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LECTURES ON BIOLOGY.

Delivered before the Catholic University of America

BY

DR. R. W. SHUFELDT.

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Lectures on Biology.

BIOLOGY

I. Its History and Present Domain.

II. Its Relations to Geology.

III. Its Value as a Study.

IV. Its Growth and Future Influence.

By Dr. R. W. SHUFELDT.

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PREFACE.

As the writer states in the leading paragraph of the first of the four lectures here offered, they were delivered in response to an invitation of the Right Reverend Rector Bishop Keane, of the Catholic University of America, and addressed to the faculty and students of that institution and an audience of ladies and gentlemen coming principally from the city of Washington, D. C., and gathered in the public lecture hall of the University, that seat of learning being situated but a few miles from the aforesaid city.

The lectures were delivered in the order they are here printed, and upon the four Thursday afternoons in the month of January, 1892, between the hours of four and five o'clock.

The author of them not being a Roman Catholic in any sense of the word, nor even an acceptor of the fundamental requirements of the Christain faith, it was a matter of no little surprise, and, it may be added, of gratification, that he was the recipient of a call to undertake such a task, coming, as it did, from such a quarter. Surprise, from the fact that all history goes to show that Catholicism has been—ever since the dawn of learning—the open and avowed enemy of all science and scientific progress; and gratification, principally due to the evidence that, perhaps, the day was drawing nigh when even Catholics were, at last, prepared not only to listen to the teachings of science but to feel the truth of them. My sense of gratification was the further intensi-

fied by the knowledge of the fact that the University had completed all its plans to erect upon its broad grounds an expensive and substantial college, equipped with faculty, library and modern laboratories, in the halls of which were to be taught to Catholic students the various branches of the biological sciences.

Later in the present preface, however, it will be necessary for me to show that the pleasure, to which reference has just been made, did not remain an unmixed one throughout all my relations with the University and her Washington press exponents; and, as such subsequent slight jars as did occur undoubtedly are significant and have their lessons for us, they will be briefly dwelt upon in the present connection, robbed of all passion and all personality. So far as the lecturer was concerned he was invariably treated with the utmost courtesy on all occasions, by everyone having anything to do with the University, and for that his sincere thanks are here tendered. The first lecture was received by both faculty and divinity students with very general and marked approval. Not so, however, the second one, and still less, the remaining two. They were disapproved, and upon the best authority the writer learned that he was roundly denounced as a "heretic" and a "pagan," by one or two of the students in their discussions of the lectures after the same had been delivered. In one instance, it required the action of the rector to quell the feeling; especially in the case of one student, who openly expressed himself in words to this effect: "That had the lecturer lived in a former century he would have been burned as he well deserved to be." At the latter part of the last lecture, one of the "Fathers," a member of the faculty, was seen to place his fingers in his ears rather than be corrupted by listening to my heresy. When one thinks for a moment how the dreaded Inquisition dealt with anatomists, "in a former century," such acts can, by the writer, only be construed as the very greatest compliments that possibly could have been meted out to him.

Cardinal Gibbons personally requested that the lectures be published in *The Catholic Mirror*, of Baltimore, Md., and the first two did appear in that paper. Only approved portions of tnem, however, were thus allowed to see the light, and for some reason—not given—the last two were not printed at all. Another paper, *The Catholic News*, of Washington, undertook to publish them in full, and, as in the case with the *Mirror*, the first two did come out, though my remarks upon the influence of the Inquisition on the labors of early writers in anatomy were carefully suppressed. This newspaper likewise was unable to publish the last two lectures, and, after the appearance in its columns of the first one, its editor was careful to preface each portion as it appeared in part with the following caution, printed in brackets: "The University assumes no responsibility for opinions advanced by lecturers in the public courses."

After a careful second reading of my "opinions," I have been totally unable to discover a single statement that cannot be most amply sustained by the very best of evidence, and doubt whether any fair-minded and intelligent Roman Catholic can do otherwise.

So much for the history of these lectures, which are now for the first time presented in full to my readers. In most cases science has long been familiar with the facts they set forth; not so, however, I fear, the vast hosts of Catholics in this country, both laymen and clergy. So it is to them, especially, that I dedicate my labors, with the profound hope that they may read and comprehend the truths I have endeavored to convey.

I.

Its History and Present Domain.

In 1891, when the eminent head of this University, Bishop Keane, extended to me the distinguished honor of an invitation to deliver during the course of the present Winter four consecutive lectures, upon any subject that I might be pleased to elect, I was, for a time, in a degree doubtful in my mind as to what department of science I should make application for material to meet so important a duty.

Upon glancing at the subjects of lectures delivered from this chair during former Winters by my most able predecessors and upon inquiry, I discovered that the largest attendances had rewarded those who had brought before you some matter selected from man's civic history or from his literature, and it was urged upon me to adopt some similar course. But the idea by no means coincided with my own views in the premises, for, I argued, in the first place, had the University any such plan in contemplation it would never have asked a biologist to carry it out, however well he may have accomplished it; and, in the second place, I felt I was called upon to face not only an audience coming from one of the greatest scientific centers that marks our civilization, but, in addition thereto, a faculty and their pupils which represent an institution which promises to be in its methods and aims one of the broadest seats of learning throughout all this broad land. Under such circumstances it devolved upon me to select for your consideration the craft to which I have devoted more than twenty of the best working years of my life, and still, in so selecting, would invite you into fields that not only are pregnant with interest, but offer their full measure of instruction, to say nothing of the influence that instruction has upon all human pursuits and the practical ends of everyday life.

When properly interpreted and applied, the science of

biology will meet what I have just claimed for it, and it is to its study that I now invite your attention.

Biology, at the present time, has come to include that group of sciences which have to deal with all those phenomena which are exhibited on the part of living matter, and, as so defined, is sharply marked off from what may be termed the abiological sciences; as for example astronomy, chemistry and physics.

A moment's thought will make it clear that such a definition as the one just given will not only include the study of man and his works, both past and present, but likewise such special studies as, for instance, the science of sociology and the science of psychology. The last named, however, is usually considered but a department of physiology, and the first but those phenomena exhibited on the part of men in society, or, perhaps, I had better say, that science which deals with human society.

As thus drawn then at the present time, the line of demarcation between the biological and the abiological sciences is quite a hard and fast one, for, as yet, we are ignorant of any link that connects living and not-living matter.

Botany, in its widest sense, falls within the scope of the biological sciences, as does most assuredly anatomy, although in the case of the latter the student in that department deals mostly with dead matter or the cadaveric remains of animals: such remains, however, once possessed life, which is more than we can say for such an object, for instance, as a crystal or a meteorite.

Naturally, one may now ask, how about palæontology? that science which treats of the fossil remains of animals inclosed within the crust of the earth or occurring upon its surface, but in any event so closely linked with the abiological science of geology.

Well, it is, also, strictly speaking, one of the biological sciences; and, in my estimation, but one of the departments of morphology. Apart from vegetable morphology, animal morphology includes not only palæontology but that entire group of studies which formerly were classified under anatomy and comparative anatomy; in other words, animal morphology takes into consideration the study of the form and structure of all animals, whether dead, living, fossilized, or whether existing or extinct. Human anatomy is then a subject that falls within the purview of the morphologist.

All studies biological are more or less dependent upon each other, as the history of all animated nature is ex-

plicable through one great system of laws. Frequently one of the abiological sciences is a most indispensable adjunct to the proper comprehension of one of the biological sciences, and I can cite no better example than the dependence of physiology upon a thorough knowledge of chemistry; and hardly, to a lesser extent, physics. For instance, the study of the blood is an important chapter in our work upon the investigation of the phenomena of living matter; but the blood is made up of many chemical constituents, and to understand the nature of its flow through the vessels we must have recourse to the laws demonstrated for us by the physicist.

The question may be raised here, by anyone who has not followed the growth of science for the last quarter of a century, nor heeded the teachings of her earlier literature for a very considerably longer period of time, that it appears to them that the laborers in those fields have recently very sadly mixed up by these apparently new classifications, what was formerly very clear to all under the time-honored title of the "Natural History Branches." This is not the case, however, and I will now proceed to show you that many of the terms I have been using are by no means new, and even the word biology itself was first used by Lamarck in one of his works published in 1801, and that eminent naturalist meant to convey by the term almost exactly what we do at the present time—nearly a century after he wrote it—that is, a discourse upon living things or upon life.

Scientific thought, prior to the revival of learning in Europe, was more or less completely under the sway of the great impress made upon it by the immortal Greek philosopher, Aristotle. Not that many other observers of Nature and philosophical thinkers did not exist during that long lapse of time, for that would not be true, but what I do mean to imply is that however weighty were the works of those others during the long sequence of centuries before the revival of thought and learning, the teachings in science as put forth by Aristotle powerfully dominated. Although Aristotle little dreamed of the mutual dependence of the various departments of science, yet he was the first to place upon a sure footing those methods of research which, during the ages since his time, have led up to such a knowledge: in other words, he was not only an original investigator but he was a great comparer of those facts that were the fruits of his investigations. He, in reality, established the first school of comparative anatomy, or as it is now more

familiarly known to us, comparative morphology. He applied those facts to the elucidation of zoölogical problems, and taught that sound zoölogical knowledge could be gained only by a close study of nature, and a comprehension of natural laws.

When we come to think that this great philosopher of ancient Greece flourished over twenty-two hundred years ago, it is really remarkable what a mass of facts he brought to light and the extent to which he systematized them. Yet it must be remembered that anatomy, as known to Aristotle, was altogether too crude to be of any service in directions other than I have just pointed out. It was, for instance, too inexact for practical use in medicine and surgery, as was his physiology too erroneous to be of any value in medical diagnosis. He had no conception whatever of the relations between chemistry and physiology, any more than he saw the bearing of zoölogy upon the medical art and the science of surgery.

Between one hundred and fifty and two hundred years after Christ, Galen, the celebrated physician of Pergamus, had largely revised, and to no small degree extended, what had been done by Aristotle in the medical and biological sciences. About the middle of the fourth century the work was again recompiled by Oribasius, after whose time the world's history passes into the Dark Ages, a period when ignorance and barbarism ruled and all scientific research was practically abandoned and forgotten.

Zoölogy and botany were brought down to the commencement of that epoch in the works of Pliny, who flourished between three and four centuries after the death of Aristotle. We are all more or less familiar with his thirty-six volumes on natural history, consisting as they do chiefly of a compilation of the labors of others in the same field, who had lived during ages prior to his day. The work of that time-honored naturalist, although very valuable in some respects is, nevertheless, loaded with absurd stories, myths, and impossible miracles. He was entirely without any knowledge of even the very simplest laws of classification, as applied to any branch of learning in general, and to the natural sciences in particular. Still, quoting from so many, many authorities as he did, his descriptions of animals, plants and minerals long remained standard, and profoundly influenced the popular mind and its ideas about such subjects. So, as a whole, his compilations, no doubt, with all their

faults, present us with a view of the entire range of science as it was understood at the time of his death.

After the revival of learning in Europe, scientific thought was still powerfully tinctured with the teachings of the schools of Aristotle, of Galen, of Pliny and of their predecessors, and their less distinguished contemporaries. Indeed, from that epoch which saw the fall of the Roman Empire down to the time I have just mentioned, or to the beginning of the Sixteenth Century, few were those who contributed anything to the real progress of the various sciences. Chief among them, perhaps, was Albertus Magnus, who, born at Lavingen, in Suabia, in 1205, wrote a "History of Animals," in twenty-one folio volumes, which was published at Lyons in 1651. They were almost entirely devoid of any original research, and were otherwise quite Aristotelian in character. The same strictures apply to the works of Paolo Giovio and of Bock; the former, an Italian naturalist, wrote "De Romanis Piscibus," which appeared in 1524, being dedicated to the Cardinal of Bourbon; while the latter, generally known by the name of Tragus, published, in 1549, a work entitled "Kraeuterbuck von den vier Elementen, Thieren, Voegeln, und Fischen," which was stamped with the same faults that characterized the productions of the earlier writers upon the same subject.

Passing through the Sixteenth Century, we still find the same servile building upon the Aristotelian basis, the same ignorance of the affinities of animals and plants, and the same desire to more or less clothe the natural with the supernatural. Almost an entire absence of any orderly arrangement or classification of facts or forms prevailed, schemes so essential to the true progress of all knowledge. Slow digestion, however, was still going on, and during this century the groundwork laid down by the fathers in zoölogy and science was preserved by industrious hands, and by minds which, in some instances, worked remarkably well when we come to consider the times of their flourishing. During this epoch Salviani and Rondelet proved themselves to be no mean ichthyologists, who, with the physician Belon, of France, really laid the cornerstone of the modern science of ichthyology. It is rather a remarkable fact that these three naturalists, working in the same fields and so thoroughly independent of each other, should have all flourished about the same time—that is, between 1553 and 1558. About the same time Conrad

Gesner, who was born at Zurich, in 1516, was engaged upon his principal work, the "Historia Naturalis Animalium." In the four folio volumes of that treatise we but again see a series of illy selected extracts from the works of Aristotle, Pliny, and Ælian, the latter who wrote, in Greek, a "History of Animals," toward the close of the Second Century. Hardly any original matter was added, and his engravings were rude and unreliable, being regarded now more in the light of objects of curiosity rather than any value being attached to them as positive contributions to science.

One other name is deserving of mention, as representing this period, and I refer to that laborious naturalist, Ulysses Aldrovani, one of the professors of Bologna, who was born in that city, in 1527, and died early in the next century. He was of noble birth, a zealous collector, and published some works upon birds and one upon insects. Other folio volumes appeared after his death. He was a builder upon the lines laid down by Gesner, from whom he borrowed extensively, although he furthered the science to some extent by his own observations, thus adding his mite to the then slowly increasing stock of human knowledge of the natural sciences.

So much, then, for the progress that men had made in those subjects at the close of the sixteenth century. Anatomy, in so far as it took into consideration the structure of man and the vertebrates below him, had been far more fortunate during the same epoch. In the Italian school, strongest at Bologna, it grew as it did in other countries where the science was cultivated out of the teachings of Galen. Nevertheless, Mondino, a teacher in Bologna, and having every claim to being the father of modern anatomy, as early as 1315 dissected specimens of the human subject and demonstrated the position of many structures upon the bodies of two females. His descriptions, however, were much corrupted by ideas derived from the Arabian writers.

A most zealous promoter of anatomical science followed in Italy at the birth of the Sixteenth Century. This was James Berenger, who declared that he had dissected during his career over one hundred human bodies. He most assuredly made good use of them, for his contributions to a better knowledge of the anatomy of man were of the most substantial character, and many of his descriptions are distinguished for their great accuracy and minuteness. As compared with Italy, France made at first but tardy progress in anatomy, and a hundred

years after Mondino had made his brilliant demonstrations, direct from the human subject, Dubois, Fernel and Etienne, of the French school, were still almost blindly following the ancient writings of Galen, and using only the bodies of the lower animals for material. But what is still more strange, those Frenchmen were, apparently, entirely ignorant of all the excellent work that had been accomplished by their Italian predecessors in the science.

But this torpor was not destined to remain long upon a nation which subsequently gave birth to such powerful lights, both in natural science and anatomy. The young Fleming, Andrew Vesalius, was the first to enter the French arena, and throwing off the Galenian yoke, about the middle of the Sixteenth Century, he presented the learned world with a truly marvelous work upon anatomy, his dissections being all original and made both upon men, women, children and the lower animals. His engravings were exquisite, and he at once rose high in the estimation of his cotemporaries. The labors of Versalius greatly enhanced the claims of anatomy to a science, and those claims gained a still firmer foothold through the researches along the same lines made by others in the school of Bologna and elsewhere, in Italy, who soon followed him. I refer to the brilliant works of Bartholomeo Eustachi, of Columbus, of Fallopius, of Ingrassiàs, of Aranzi, of Variolus, and of Fabricius. Spain gave us Servetus, and England, the immortal Harvey, about this time.

What I have told you thus far about the growth of the natural sciences and of anatomy will serve as an example to show how other sciences grew out of the labors of the ancients, and came to be what they were in the Sixteenth Century. The career of physiology was more or less linked to that of anatomy, while botany and some of the other departments developed much in the same manner as did the last named science.

The dawn of better days had now appeared in Europe; human knowledge was again awakening into life; the taste for learning was once more being appreciated, and in defiance of persecution, the faggot and the Inquisition, scientific culture had taken on a career which, in all probability, is destined not to be checked again in the history of humanity in time to come.

Just here it is important to observe the interesting fact, that the scientific writers, down to the time of the decline of the Roman Empire, rarely or never confined their observations to any single department, but, on the contrary,

owing to the then limited knowledge of the age, passed everything known to their time in such fields in review. Aristotle was such an one as we have seen, and so likewise were Pliny the Elder and Galen. Practically it may be said they employed no classification, and they were ignorant alike of the mutual affinities and relation of things, as they were of any rational scheme of the material world.

At the revival of learning much of this had changed, and notwithstanding men wrote in science with their minds fettered by the works and teachings of their ancient predecessors, yet a decided step in advance had become evident, inasmuch as men occasionally confined themselves to special departments, such as zoölogy, anatomy, botany and the like. Zoölogists, as we have seen, however, consulted Aristotle far more often than they did Nature, and anatomists more frequently taught from the pages of Galen than they did from the only safe guide, the human cadaver, upon the dissecting table. All existing forms were supposed to have been created within a comparatively recent time, and no species had materially changed since the date of that creation. Where any notion of the affinities of species of animals inhabiting the earth existed at all, such notions were of the vaguest nature imaginable. Classification, consequently, in their works simply resolved itself into the alphabetical arrangement of the forms described. The love of incorporating into works of science descriptions of the marvelous and the mythical prevailed almost everywhere. In those times, too, man was studied as one thing and Nature was studied as another, and the two were considered to be antagonistic to each other; indeed, a sort of essential antithesis existed between them, which even in those early days of history gave rise to some puzzling speculations. As crude, however, as was the then knowledge of Nature and the material scheme of things, the foundations, nevertheless, had been lain, and that, too, in very solid masonry, for a more or less systematic gathering of facts. That structure is by no means completed at the present time, notwithstanding the laborers upon it have been increased many, many thousand fold.

Time passed on and the number of those who were interested in the various sciences gradually increased. In 1651 Thomas Hobbes wrote: "The register of knowledge of fact is called history. Whereof there be two sorts, one called natural history, which is the history of such

facts or effects of Nature as have no dependence on man's will; such as are the histories of metals, plants, animals, regions, and the like. The other is civil history, which is the history of the voluntary actions of men in Commonwealths."

From these words it will be seen that at least one good thinker of the middle of the Seventeenth Century, recognized the distinction between what soon came to be designated as natural history, and civil history. A few years afterward, when Newton's great work, the "Principia," appeared, other lines commenced to be drawn, and it dawned upon men that certain of the sciences especially required the application of mathematics in their treatment, as was the case in physics, astronomy, and other branches. As these developed they naturally became differentiated from those which took into consideration the phenomena of Nature, and especially demanded the exercise of the observational powers of men. Again, other departments of human knowledge were in those days arrayed in another series, depending upon the fact whether the phenomena they presented for consideration were susceptible of explanation or were dealt with by experimental methods or fell within the treatment of both. Thus the old science spoken of as "natural philosophy," was gradually drawn away from astronomy and chemistry began to occupy a field of its own. It was thus, as time went on, that the persons designated as "naturalists" were those who devoted themselves to the study of the history of plants and of animals, to physical geography, mineralogy and geology, and those branches were considered to constitute "natural history." As thus defined, however, it will at once be clear to you that natural history meant to Aristotle and to Buffon two widely different things; the latter understood it to mean precisely what I have just given you. Indeed, to some extent, at least, the meaning which Buffon attached to natural history has endured down to our time, and no doubt not a few of those of my audience can well remember in their boyhood days how it fell to the lot of one of the professors in college to assume the duties of the Chair of Natural History, and such a person was designated as the Professor of Natural History, and essayed to instruct his class in not only the history of plants and animals but in mineralogy and the entire field of geology besides. So far as I am aware, we never hear of a professor of natural history in any of the leading universities or colleges of this coun-

try at the present day, for the reason that the marvelous progress that science has made in this century has demanded a still further division of labor in such fields. Gradually both geology and mineralogy came to occupy their own legitimate spheres, and the geologists and the mineralogists ceased at last to be classed with the naturalists.

Glancing backward again, from this period, we find that in due time men outgrew the practice of making mere alphabetical lists of the animals they studied and recording random notes about them. Something more was demanded, for work of that nature could not always satisfy the orderly and the growing mind of the age. It was knowledge to be sure, but it was not classified knowledge, nor did it make any attempt to solve the relations of the things described. It rapidly began to dawn upon men that there were but few forms in existence, comparatively, that had not their affines, the affinity shown being more or less near. For example, it was appreciated that such forms as the wolf, the hyena, the fox, and the dog were in some way or the other related to each other and were easily distinguished from some other distinct group, as one represented by the lion, the tiger, the puma, the cat, the ocelot, and so on. These same principles became also evident in botany, and were duly applied there as they were in other scientific departments. Botany showed especial early development owing to its relation to medicine, and the additional inducement to study it to that end. Many of the herbs were valuable as articles of the materia medica, and early in the Seventeenth Century the number of working botanists, it is said, far outnumbered the zoölogists. Among the first of these latter who resorted to a classification of the forms he studied, was that erratic Dutch naturalist, John Swammerdam, who was born at Amsterdam in February, 1637. His numerous works appeared from time to time during the latter part of the century in which he lived. His methods of classification were best seen in his entomological researches, and it will at once be observed by those at all familiar with the subject that his ideas in those premises are very different from the corresponding ones entertained by those engaged in the classification of insects in our own day. Swammerdam divided all insects into four classes, based upon the development of the various kinds as understood by him. He took into consideration the condition of the species immedi-

ately after its birth, as well as its various metamorphoses afterward.

In his first class he placed the spiders and other species which upon hatching have a form more or less like the parent form. In this group he also included the slugs, and leeches, which, of course, are not insects at all. A second class included the grasshoppers and their kind, or, as he points out, those insects which have six feet upon being born and at a later period shed that covering beneath which the future wings are hidden. He was also struck by the jumping power of this class. Thirdly, he had a class for the caterpillars, which, as we know, are hatched as worms and later assume the various chrysalis forms, and still later emerge as moths and butterflies and their allies. Lastly, or in his fourth class, he placed such insects as the common fly, which emerge as worms upon hatching from the egg, and later assume a pupa stage enveloped in an investing shell of their own, which protects them until they take on the winged state.

Swammerdam in many respects was a remarkable man; his personal history forms one of the most interesting pages on the growth and development of zoölogical science. Toward the close of his life, he carried his studies to such an excess as to utterly ruin his otherwise powerful constitution; he then became a fanatic in religion, careless of his work and its results, and, finally, died a victim apparently of melancholia brought on by his unhealthy religious broodings. We must believe that somewhat earlier in his life, or about 1674, these were much aggravated by the control over his mind which had been gained by that notable mystic, Antoinette Bourignon, a woman whose religious ideas and professions were by no means carried out in her daily course of conduct.

In England, Sir Hans Sloane and Jno. Ray, during the latter part of the Seventeenth and early part of the Eighteenth Centuries, accomplished a great deal to place the natural sciences upon the most substantial footing. Ray especially was a very learned man, and a voluminous writer upon subjects connected with his chosen profession. With two or three favored pupils he traveled much over Europe, and made some very admirable and extensive collections in animals and plants, which were brought back to England to be worked up at his leisure. Ray also did much toward classifying the forms he studied, and as a rule his terse and classical descriptions were excellent, which same favorable criticism, however, cannot be extended to

his figures and plates which illustrated them. We must remember, though, that the time had not yet arrived when ease, grace, artistic skill and accuracy were thrown into zoölogical illustrations. In birds, the world had to wait for Audubon to demonstrate the manner in which that was to be accomplished.

Sir Hans Sloane, who was born in Ireland in April, 1660, and died at Chelsea early in January, 1752, was a stanch promoter of the cause of science. He is especially to be remembered as, after his death, his enormous private collections of objects in natural history formed the nucleus from which the British Museum afterward developed and grew.

The year 1683 produced also a remarkable man in France, the genius of whose work reaches down to the present time. This was René Antoine Ferchault de Reaumur, a man who not only greatly advanced the science of biology but in addition made a powerful impress upon nearly every other branch of learning of his day. As you well know he invented an admirable scale for one of the styles of thermometers still in use in many parts of the world. Reaumur completed and published in 6 volumes a work upon insects, and left several others incomplete and unpublished, which is very much to be regretted as much of his work is very valuable. Some of his philosophy in those memoirs would hardly hold good at the present day. In speaking of insects, he says: "The number of observations necessary for a tolerably complete history of so many minute animals is prodigious. When one reflects on all that an accomplished botanist ought to know, it is enough to frighten him. His memory is loaded with the names of twelve or thirteen thousand plants, and he is expected to be able to recall on occasion the image of any one of them. There is, perhaps, none of these plants that has not insects peculiar to itself; and some trees, such as the oak, give substance to several hundreds of different species. And, after all, how many are there that do not live on plants! How many species that devour others! How many that live at the expense of larger animals, on which they feed continually! How many species are there, some of which pass the greater part of their time in water, while others pass it entirely there! The immensity of Nature's works is nowhere more apparent than in the prodigious multiplicity of these species of little animals." He then proceeds to show the utter impossibility of man ever

gaining even a modicum of knowledge of a subject so vast, and argues the necessity of simply knowing the principal genera and the leading or characteristic species in each genus. He adds: "Although we would greatly restrict the limits of the study, there are persons who will think them still too wide; there are even some who consider all knowledge of this part of natural history as useless, and who unhesitatingly pronounce it a frivolous amusement. We are equally willing that these pursuits should be regarded as amusements, that is, as studies which, so far from being troublesome, afford pleasure to the person who engages in them. They do more, they necessarily raise the mind to admire the Author of so many wonders. Ought we to be ashamed of ranking among our occupations observation and researches, of which the object is an acquaintance with the works on which the Supreme Being has displayed a boundless wisdom, and varied to such a degree? Natural history is the history of his works; nor is there any demonstration of his existence more intelligible to all men than that which it furnishes."

It is nearly a century and a half ago since Reaumur published these views, and we can well imagine what his surprise would be were it possible for him to stand in our midst to-day. Not only have the botanists since his time added many, many thousands of new species of plants to the lists, but the entomologists have simply increased to an enormous extent our knowledge of the insect world. We have in the neighborhood of one million species described, and propose to describe every new form that comes to hand. Nor is this all, for the structure of these minute creatures is being exhaustively studied in all directions by many minds and many microscopes; their habits are being closely observed and recorded; their sex variations and metamorphoses determined; the insect parasites upon insects and upon other animals are receiving continuously the same kind of study. Out of all this work is growing an enormous literature, but more than that the government in this country has taken the matter wisely in hand, and an annual appropriation supports a staff of eminent workers who constitute our Bureau of Economic Entomology, and I am quite confident that even Reaumur, were his eyes opened, would not consider their labors in the light of a "frivolous amusement," and we are well aware that the highly valuable investigations of the staff of workers, to whom reference has been made, is having the excellent and practical result of being of the

utmost importance to horticulturalists the world over, wherever their works have come known and appreciated. Moreover their published accounts of the habits and development of insects are of value in no end of other ways, and explain many practical and theoretical questions.

To return now to the middle of the Seventeenth Century, we find that meanwhile an ever-increasing host of workers in the service of anotomy have attained to many glorious results. Through the labors of Asellius, Glisson, Jolyffe, the Englishmen, and Rudbeck, the Swede (the last two who divided honors upon the distinction between the lacteals and the lymphatics), Willis, who carefully studied the nervous system, and Malpighi, who devoted himself principally to histology, and to Steno, Ruysch, Swammerdam, who has already been noticed, and to a hundred others the very refinements of anatomical researches were being then annually published. A complete knowledge of man's structure was rapidly being gotten at: and, what is fully as important, a very general comparative knowledge of the morphology of many other animals was likewise having a powerful light thrown upon it, and with the effect of very materially elaborating what was already known in such fields. It was through these latter studies, supplemented as they were by the descriptions of mammals by the naturalists of the time, that the science of mammalogy was kept fully abreast the other departments of natural history. Comparative physiology, ichthyology, invertebrate zoölogy, herpetology, and ornithology were also advanced by more or less similar methods, though no one of them by any means ever in the same degree. Palæontology, or the knowledge of the fossil remains of animals, at first grew but slowly, and it has only been within the last fifty years that it has been brought up into line with the other sciences, as they are understood at the present day, and made its influence most powerfully felt.

By the middle of the Eighteenth Century great interest was evidenced in travel and exploration, and many countries were being explored by Europeans prompted by a variety of motives. Some went abroad from the sheer love of adventure; some sought wealth and fame; some explored in the interest of science and geography; while others made up the sightseers. It all tended, however, to produce in the main very good results and was especially favorable to the growth of all the natural sciences. One very im-

portant branch was benefited by it, and one that hitherto had not been much developed. and that was the knowledge of the geographical distribution of animals, a most important subject, as we shall hereafter see. Material now, from all quarters of the globe, in the shape of plants, animals, and similar objects of interest came in abundance to Europe, where it poured into the museums or enriched the collections of universities or those of private individuals.

The age was ripe for a master mind; some great, all-absorbing intellect to encompass and digest this incoming store of wealth; to arrange, describe and classify it in due and orderly manner; in that it might come to be a true and living part of human knowledge, and capable of being comprehended, made useful, studied and appreciated.

When Nature is prepared to inaugurate another epoch, to turn over as it were another page in the history of the world, it would seem that one of sufficient strength is invariably forthcoming to perform the operation, and such an individual arose in the middle of the last century, to do the realm of nature that service. It proved to be Carl Von Linné, or, as he is better known to English ears, Charles Linnæus. This master genius was born at Rashult, in the province of Smaland, Sweden, in the latter part of May, 1707, and the term of his life spanned seventy-one years. Mr. Jackson, of the London Linnæan Society, tersely expressed the influence that Linné's personal magnetism, public lectures, teachings, and his one hundred and eighty published books and papers had upon natural science, when he said: "He found biology a chaos; he left it a cosmos." With him classification was a passion, and the description of natural objects a pastime that occupied every moment of his thoughts. To botany he gave the natural system of classification, or a classification based upon a knowledge of the structure of plants, their flowers and fruits. This, his original scheme, has come down to us through a century and a half of time, in practically the same principle as when it left his hands. He revolutionized the entire system of nomenclature by his use of generic and specific names and by the employment of the higher groups used in taxonomy. Linnæus' mind, however, appreciated probably little or nothing of what a species really is, or what species are now known to be in the light of modern research. To him a species was an immutable integer; when once found and properly described it was good for all time, as it was good as an expression of what that

form had been since it came into existence Genera consisted in groups of such species, defined by their generic characters. *A'ca impennis* was one species of auk, and *Alca torda* another, two species of auks belonging to the *genus Alca*—or, again, in mammals, we find the order *Cete*, containing the whales; within this order the genus *Balæna*, created for the whales proper, of which he duly described four species. Such simple and far-reaching innovations; such effective machinery made itself felt in comparatively a very short space of time in every biological laboratory and study, either public or private, throughout the then learned world.

Linnæus's greatest achievement was his "Systema Naturæ," of which there have been numerous editions. In it, in the manner I have described, he swept over and passed in review in orderly classification all the departments of natural history as they were recognized in his time. Its publication gave an enormous impulse to the progress of science along the lines indicated. But this great man was mortal, and he possessed the failing as has every naturalist both before and since his time, of making mistakes, and Linnæus made a great many of them. Mistakes, however, have their uses, even in biology, and from their correction by future laborers much additional information and research is apt to accrue. The vast majority of the Linnæan errors have been rectified in our day. Macgillivray, who has written a very good biography of the immortal Swede, said: "All systems flourish and fade. The mineralogy of Linnæus has perished; his zoölogy, cut down to the root, has sent forth a profusion of luxuriant shoots; and although his botany maintains as yet a strong claim upon the admiration of the lovers of Nature, a fairer plant has sprung up beside it which promises a richer harvest of golden fruits. But should the period ever arrive when all that belonged to him of mere system and technicology shall be obliterated, he will not the less be remembered as a bright luminary in the dark hemisphere of natural science, which served for a time to throw a useful light around, and led observers to surer paths of information than had previously been known."

These words, from the pen of the Scotch naturalist, from whom I have quoted them, were printed in 1834. I give you the date simply to show the trend of thought of some naturalists, and Macgillivray was a good one, over fifty years ago, upon such subjects.

We must not, however, measure the growth of the natural sciences too closely by the arbitrary scale of the century, which is nothing more than a human estimate invented for man's convenience in reckoning time. Biology has been a natural growth, like anything else, at times being rapid and luxuriant and again sluggish and uncertain, but ever independent of either B. C. or A. D., or any other time-gauge of our devising. When at any stage in the course of this growth it received into its ranks the right kind of recruits, these latter came prearmed with the knowledge of much that had been done before their joining; and in taking up the torches of their predecessors, in their various spheres of action, they nearly always succeeded in still further illuminating the conquered domain, and by their excursions into the unknown added additional territory. Very often the workers along some line, or upon a number of lines, have been engaged for great lengths of time in simply gathering in harvests of material and rendering descriptive accounts of the same. Very little generalization is done; and evidently without design the years roll by for a time, and the entire corps of the world's naturalists appear to have run into an army of fact gatherers. Facts are seized up and accumulated from all quarters, and are of the most varied nature. Sometimes, from their very remoteness from any apparent utilitarian ends, they for the time have been regarded by many as practically valueless; but we are bravely getting over such views of any kind of true knowledge, for our experiences are teaching us now that every real fact discovered and comprehended far from being useless is sure some day to have its place found for it in the grand structure of human understanding of the scheme of the universe. Frequently such facts build up a philosophy for one age, which is more than likely to become the common sense of the next succeeding one. Explorers, traders in foreign seas, material gatherers and the describers of museum material, zoölogical artists and popular writers on natural history, together with here and there occasionally a stronger hand and more far reaching researches, were a long, long time filling the biological magazine for some great digester of the whole, some great mind and hand to sum up in orderly arrangement the grand total of results attained; to make an epoch; to spread a broad, solid base for the succeeding host of investigators to rest upon. We have already seen how a Linnæus arose, nearly two hundred years ago, as the transcendent systematizer of the

great mass of information that had been accumulating to his hand; and I doubt not even Aristotle, the ancient sage of the peripatetic school in Greece, over 2,000 years ago, had his material and fact; and we may add, his myth collectors, whose life histories dip far back into the pre-traditional times of man's career upon earth, and into ages of which we have no history.

It can now be appreciated that ninety odd years ago an enormous mass of material and facts were again, and had been, accumulating since the Linnæan period; and, in half a century thereafter, a Charles Darwin came upon the scene to handle them as a whole and in due course to flash to the world their significance.

We are now in a position to glance at some of the work that was being done at about the beginning of the present century, and to pass in review some of the ideas entertained by the biological writers of that time. It was nearly sixty years prior to the appearance of Darwin's "Origin of Species," and yet Erasmus Darwin, his distinguished father, in his very interesting work, "The Temple of Nature, or, the Origin of Society" (a copy of which I have in my library and which was published in Baltimore, in 1804), says in the first Canto, on the Production of Life;

"Organic life beneath the shoreless waves
Was born, and nurs'd in Ocean's pearly caves;
First forms minute, unseen by spheric glass,
Move on the mud, or pierce the watery mass;
These, as successive generations bloom,
New powers acquire, and larger limbs assume;
Whence countless groups of vegetation spring,
And breathing realms of fin, and feet, and wing."

In an explanatory footnote to these lines he is careful to say: "The earth was originally covered with water, as appears from some of its highest mountains consisting of shells connected together by a solution of part of them, as the limestone rocks of the Alps;" (so much from "Ferber's Travels," to which the author of the "Temple of Nature" adds: "It must be therefore concluded that animal life began beneath the sea."

It is unnecessary to point out in this place the double fallacy in this theory, for, thanks to our geologists, the knowledge of the mode of the formation of mountains is now well understood, and the occurrence in them of marine shells easily explained. Still Erasmus Darwin's notions of the origin of life are far in advance of the

ideas of John Milton on the same subject who wrote in his "Paradise Lost" somewhere about 1667,

"The sixth, and of creation last, arose
With evening harps and matin, when God said,
'Let the earth bring forth soul living in her kind,
Cattle and creeping things, and beast of the earth,
Each in their kind!' The earth obeyed, and, straight
Opening her fertile womb, teemed at a birth
Innumerous living creatures, perfect forms,
Limbed and full grown. Out of the ground uprose,
As from his lair, the wild beast, where he wons
In forest wild, in thicket, brake or den;
Among the trees in pairs they rose, they walked;
The cattle in the fields and meadows green;
Those rare and solitary; these in flocks
Pasturing at once, and in broad herds upsprung.
The grassy clods now calved; now half appears
The tawny lion, pawing to get free
His hinder parts—then springs, as broke from bonds,
And rampant shakes his brinded mane; the ounce,
The libbard, and the tiger, as the mole
Rising, the crumbled earth above them threw
In hillocks; the swift stag from underground
Bore up his branching head; scarce from his mold
Behometh, biggest born of earth, upheaved
His vastness; fleeced the flocks and bleating rose
As plants; ambiguous between sea and land,
The river-horse and scaly crocodile,
At once came forth whatever creeps the ground,
Insect or worm."

I have already told you that it was about 1801, the celebrated French naturalist, Lamarck, was the first to use the word Biology; this you will see was about the time that Erasmus Darwin published his "Temple of Nature;" and, Lamarck, in his "Philosophie Zoölogique," remarks: "Everything which Nature has caused individuals to acquire or lose by the influence of the circumstances to which their race is long exposed, and, consequently, by the influence of the predominant employment of such organ, or its constant disuse, she preserves by generation to the new individuals proceeding from them, provided that the changes are common to the two sexes, or to those which have produced these new individual." (i, 235). The significance of these words must be clear to all, and yet they were written nearly sixty years before Charles Darwin published his "Origin of Species," and

very well show the trend biologic philosophy was taking in some directions at the very beginning of the present century.

It is very important to trace back, here and there first glimmerings as light that illuminate such laws, and take cognizance of their source, for the idea is far too prevalent, even yet, that the demonstration of the origin of organic life in this world arose in any one man's mind. That demonstration had been a growing one for many years prior to 1859, and has come up in the same way that other biologic truths have come up. And, in this connection, you will remember that even as early as Cuvier's time, that great *savant* wrote of the eminent French naturalist, Buffon, that he had "the merit of having been the first to point out clearly that the actual condition of the globe is the result of a succession of changes, of which we can find the evidences to-day; and it is he who first drew the observation of all investigators to the phenomena by which these changes can be unraveled." Buffon's work on natural history commenced to be put forth in 1749. But we must pass again, after this momentary digression, to those biologists who wrote fifty years subsequent to the date I have just mentioned. I will refer, however, to but a few. In human anatomy, works comparable with the modern system of treating the subject appeared first rather less than a century ago. The second or German edition, of the work on anatomy, by Sommering, inaugurated a new era in this branch of human knowledge, for that eminent authority grasped the subject in a most masterly manner, and his published labors are characterized by marked accuracy, philosophical arrangement, and by evidences of exhaustive research. In 1801 the French philosopher, Bichat, brought out in four octavo volumes an equally excellent treatise upon human anatomy, and both he and Sömmering greatly advanced the knowledge of physiology. These two great men were the center lights of the French and German schools at the time they flourished. About each were workers in the two countries of scarcely less celebrity, while in Great Britain John Gordon, Bell, the third Munro, Jones, Quain, and others carried the subject fully up to the time. Great precision was now being gained by the use of the microscope and other instruments ensuring more accurate results in dissecting. Means of more extensive criticism and reviews reacted most beneficially, and many special treatises rapidly appeared in Germany,

England, France, Italy, and elsewhere on the continent in wonderful profusion.

Morphology of vertebrates, other than man, was also advanced most satisfactorily, and during the first thirty years of this century a comprehension of the structure, organization, physiology and composition of all organic forms was fairly established, and as the years swept by they were marked by an ever-increasing host of investigators of all those departments, and by a most remarkable giving-to-the-world of a perfect flood of literature upon every branch of biology; not only those I have just mentioned but also botany, palæontology, invertebrate zoölogy, man and all that refers to or concerns him, pathology and psychology. This great wave of intellectual activity swells up to the present hour with a powerful augmentation of its force, propelled as it is by the minds of an army of restless investigators, that annually enlist a greater and a greater number of recruits. So long, indeed, is this list of honored names, that even to mention those who have distinguished themselves in the various departments of biology during the time since the commencement of the present century would be absolutely impracticable, as that list, with even a reference to the principal works in each case, would fill several goodly volumes.

What have been some of the results of all this study and investigation? They are not far to seek, but, as it is my intention to revert to some of them more fully later in the present course of lectures, only a few of the main ones will be named in this connection. We saw that early in the history of the biological sciences men but very slightly appreciated either the unity of organization as it exists among plants on the one hand, and animals on the other, or were they scarcely at all aware of the mutual relations of the biological sciences. Now modern science and research, in the first place, has brought about a very thorough realization of the interdependence of her various natural divisions; and in the second place, the general uniformity in the plan of structure of all animated beings is now well known.

Palæontology and the microscope are largely responsible for these results; the former demonstrating the relations of living things in geologic time, and the latter bringing to light the agreement in kind of the few elements or tissues throughout animated nature and out of which all organic forms are composed and built up.

Attention was first turned toward the question of the unity of plan in the case of the vertebrata by the poet Goethe. who, early in the present century pointed out the fact that the premaxillary bone or that element of the skull which supports the upper incisor teeth, occurring, as it probably does in all backboned animals, should occur in man. This he finally demonstrated to be true, and its demonstration, taken in connection with the theory of Oken on the vertebrated nature of the entire skull, a lecture given by that transcendent anatomist at a time when Goethe was present, turned the attention of all leading anatomists of the time to making comparative studies of animals, often with the view of elucidating some obscure structure in the organization of man. Since the time of which I speak comparative morphologists have made, without any exaggeration, thousands upon thousands of such comparisons, and the truth of the unity of plan of structure among the vertebrata is as well established as is the form of the earth. Botanists find that essentially the same holds true in the vegetable world. So that were one to fully study any single well-chosen plant, in all its details, he would practically possess the key to the knowledge of the morphology of plants, both living and extinct. So also for the physiology of plants; so also for the physiology of animals, a full comprehension of physiologic laws, as exemplified in a tortoise, are found to obtain with the same exactitude in an elephant. In other words it has come to be known that certain broad laws concerning such matters possess a general application throughout both the vegetable and animal kingdom.

Another great subject has come to be very largely understood through the labors of the biologists of this century, and that is the geographical distribution of plants and animals, both for those now existing and for those which existed during former ages of the world but are now extinct. This is a very important field as we shall hereafter see.

Still another vast problem of prime importance has been elaborated within the last hundred years, and to it the millions of facts drawn from all departments of biology lend substantial support. I refer to the doctrine of the generation of living beings; the probable origin of life upon the globe; the development of the individual, the development of the tribe; the history of animals and plants throughout all time; and, finally, a

very general comprehension of the laws and factors of this doctrine considered in its entirety. When we come to search for the physical basis in the economy of any living thing in the whole world, it invariably results in the discovery of an apparently structureless mass, to which the name of protoplasm has been given. This fundamental form of all life; this morphological unit is the material, in so far as our present knowledge carries us, from which every organ, however complex or however high in the scale of organization in either the animal or vegetable kingdom, is built up. Among some of the lowest forms of existing life we find that, structurally, they are but slightly advanced beyond this protoplasmic matter; whereas in man or any other complex animal, his system is found to be made up of organs and tissues, which organs and tissues are in turn found to be simply an aggregation of protoplasmic cells, that present various modifications in form, which latter takes on an internal structureless part and an external part which appears to be more definitely constituted. Further, it is apparent that this living matter, considered in its simple state, holds a definite position in space and in time; it may be acted upon by certain forces, which result in the production in it of certain internal changes or causes it to modify external objects, which in turn may modify it. So that, finally, its very form, or the place it occupies, or what it is capable of doing are controlled by the effects of certain causes.

Our ablest biologists then subdivide the entire subject of biology into four parts, that is, into morphology, distribution, physiology and ætiology.

As I have already pointed out, under morphology we take into consideration both the minute and gross anatomy of all living forms, together with their development. Such knowledge is made comparative, and taxonomy or classification flows from it as a natural result.

Under distribution we arrange all the facts that bear upon the occurrence of living forms over the surface of the globe, and the laws that appear to govern it, as well as the geographical occurrence of animals and plants during former geological epochs of the earth's history.

Under physiology we have to deal with the functions of living matter as seen in the representatives of the animal and vegetable worlds, of the function of an organ of any living thing as a whole, and the functions of the morphological units or cells of which any living thing is composed. Secondly, of the various modes of reproduc-

tion of animals and plants, and the laws that control their existence. Thirdly, of the question of the hereditary transmission of characters and the laws that operate in producing variation in those characters, both in consecutive and non-consecutive generations. Psychology and sociology are also legitimate branches of this subdivison.

Finally, under ætiology we are concerned with the questions of, first, the probable origin of life upon the earth, and with the causes of the phenomena of the same. In the second place, with the causes of the variations presented on the part of animals and plants in time, as well as the history and causes of the evolvement of living forms and the laws pertaining thereto. The phenomena of morphology, physiology, and distribution are based upon known facts, whereas much that ætiology has to do with, is speculative, though often amounting to a degree of probability bordering upon absolute certainty, inasmuch as it is in complete harmony with and renders full explanation of many of the known phenomena of the three first-mentioned grand subdivisions of biology.

Thus you will see how our science has grown and developed, and the manner in which the subject presents itself to the minds of the best interpreters of Nature to-day, and how the problems concerning life itself are regarded.

Upon the next occasion of our meeting I will endeavor to lay before you the evidence we possess bearing upon the question of the relation of biology to geology. And in doing so I shall select the vertebrata as the group wherewith to point out that relationship, at the same time fully assuring you that the facts we will have to deal with hold true in principle for the invertebrata as they likewise do for the entire vegetable kingdom. It would be impossible in the short space of time represented by one of our lectures to deal with this subject by attempting to demonstrate the bearing of the entire animal and vegetable worlds, as they now exist upon the face of the earth, to the science of geology, for the range is far too wide; and, as I have first said, essentially the same laws obtain throughout. Although I had not the pleasure, last year, of attending the lecture given you by Prof. Lester F. Ward, upon palæobotany, I feel quite sure he must at that time have had not a little to say respecting the affinities existing among the various modern floræ and those fossil plants which have been

discovered from time to time in the various geologic horizons making up the crust of the earth. This is especially fortunate inasmuch as that aspect of the subject has thus been brought before you by one of the most able of all living polæobotanists, as it does at the same time relieve me of the necessity of passing into similar fields for facts for my next lecture, e'en had I the ability to present the matter with that lucidity and breadth that I have no manner of doubt was done for you by Prof. Ward.

Finally, to those who may be especially interested in the present course of lectures and at the same time consider themselves to be but tyros in the science of biology, and desire by their reading to look into the subject of each succeeding lecture, prior to my delivering it, I would say that in considering the relation of biology to geology we will also take into consderation the question of the geographical distribution of many of the groups of the world's existing vertebrata, as that is a matter of prime importance to be dealt with, to the end that we may attain to an understanding of the subject in chief.

II.

Its Relations to Geology.

As stated in my last lecture, to arrive at anything like a fair comprehension of the relations of biology to geology, we must first gain some general understanding of the question of the geographical distribution of existing forms of life. It was also pointed out that in order to be enabled to enter upon this important subject with any degree of thoroughness at all, it would become necessary to limit ourselves to some one of the great branches of the animal kingdom, and through it seek to illustrate the main facts, as they are now known to biologists, which pertain to the matter of the distribuiion of animals and plants over the face of the globe. For this purpose the vertebrata offer us as useful a group as any one that could be selected. The vertebrata, as you know, is that most important branch of the animal kingdom which includes all the back-boned animals, or the mammals, birds, reptiles, batrachians, fishes and the like; and from all these the distinguished British zoögeographer, Mr. A. R. Wallace, chose the first class or the mammalia from which to deduce the principles of the science of zoögeography. Upon applying these principles to other great groups of animals and to plants it has been found that in the main they are in harmony with them, and where decided exceptions exist they serve to explain questions that would otherwise be in doubt.

Now zoögeography is a scheme by means of which we can classify our knowledge of animal distribution and in an orderly manner present it to the mind so that it can be easily appreciated. Many scientists have devoted years of study to this subject alone, and among them we must not neglect to mention, in addition to Mr. Wallace, already referred to, the names of Buffon, the eminent French biologist, Agassiz, Allen, Gill, of this country, Sclater of London, and Alexander Von Humboldt. In the present connection, however, it

will meet my purpose very well to adopt the views in the premises as so ably set forth by Mr. Wallace. As is the case with other departments of science, zoögeography has grown up from early and crude notions of its principles to its now largely elaborated state. With respect to the occurrence of animal and plant life over the face of the earth, most of our American zoölogists divide the land and water areas into divisions in chief which they term "realms," while our British confreres give the name of "regions" to those areas. But before giving the names of the zoögeographical regions of Wallace, I wish to bring before you some of the general facts in reference to animal distribution. In speaking of the characteristic forms of animal life of any part of the world's land or water areas, we refer to it as the *fauna* of that part, as in making reference to its plants we speak of them as the *flora* of the same or other parts. We also use special names to designate what classes or groups of classes of animals we may have independently under consideration, as, for example, the birds of any district are referred to as the avifauna of that district, as are the fishes of any special body of water as its piscifauna. Elsewhere I have made use of the convenient term anthropofauna in allusion to the race or races of men that occur in any region, and similar words for other groups will readily suggest themselves to you.

Now it is a well-known fact that certain classes of animals are practically confined to the dry land, while others are inhabitants of the fresh water, and still others of the salt water; and, lastly, some are common both to waters that are salt and to waters that are fresh. These various kinds not only differ, but still another difference is to be observed in any given locality when we either gradually ascend or descend; that is to say, the flora and fauna at the base of a mountain are usually very different from the flora and fauna at different elevations on the side of the mountain; and the same holds true for the animals found at various depths in the ocean or great fresh water lakes. Again, divers latitudes, characterized by different climates, have also their characteristic assemblages of plants and animals, and even in different longitudes, where the climates may be almost identically the same, the living populations are again found to be dissimilar.

Not only do differences of latitude and longitude, differences of climate, elevation and depths in the water influence the kinds of animals and plants found in those

various parts of the world, but the diversity in the physical geography of the earth's surface is another powerful factor in determining faunal and floral limits. Plains may encourage extended migrations, as do hills, mountains, large rivers and seas check the same. The abundance or absence and scarcity of certain foods over certain areas also have an influence. In many cases the faunal limits can be but loosely defined, as any faunal district may almost imperceptibly merge into any one of its adjoining ones, but certain surface contours may often, on the other hand, sharply define some of the boundaries, and animals of the contiguous areas not pass over the line. Some species range through several faunal areas, others are never found beyond, perhaps, some quite limited locality, these several restrictions and diffusions nearly always being due to assignable natural causes. Where certain species arrive at their maximum of abundance it is generally supposed to indicate the area of the origination of that species.

Soils also play their part, and it will be clear that the fauna of extensive marshy districts are sure to be quite unlike the fauna of a great desert; indeed, in the case of the latter, it has led an eminent authority to say that "deserts may act much as inland seas to separate the animals of the adjoining more fertile tracts, and they afford dwelling-places for animals which are incapable of living elsewhere. Desert faunæ have a general *facies* the world over, though the original elements out of which the faunæ have been made up may radically differ."

Although a great ocean, such as the Pacific or the Atlantic, forms almost a positive barrier to the spread of the land animals of its opposite coasts, which are invariably quite distinct, yet at the same time, within its own self, the great ocean currents form means of dispersal of prime importance for many land animals and the vast majority of marine forms. Again, as we have already pointed out, climate in most cases is a positive barrier to the spread of animals in many directions, whereas the alternation of the seasons, and even the severity or mildness of the Summers and Winters powerfully urge many animals to migrate, and thus for the time being, at least, to pass beyond either their local or general faunal areas. Migrations from such causes, in the main, however, take place within the boundary of any faunal region where they occur. A familiar example of this is our own United States vernal and autumnal migration of birds

which takes place every year, and that for the entire width and breadth of the continent.

As another means of the dispersal of animals we have those various movements which take place in the atmosphere itself, and it has been noted that the trade winds, hurricanes and cyclones, or even the minor whirlwinds do much sometimes toward scattering the lighter forms of animal life as well as the seeds of many plants, and by such means new organisms are often transported to distant faunal areas to which they were formerly unknown. In any special case, should the environment prove compatible to a species thus violently introduced, that species may become established and thrive in the new region, or it may, the reverse holding true, become gradually extinct, or even may perish at once.

Quite a number of artificial means, introduced by man, himself, have from time to time acted as factors in either favoring the dispersal of certain animals or tending to restrict them to certain localities. Bridging large streams, the transportation of many of the smaller forms in steamers, grain cars, trains, and other modes of conveyance; the joining of large bodies of water by means of the opening of artificial canals; and finally, even the construction of country roads have all had their influence along the lines indicated.

Anticipating for the moment the discussion of the main subject of our lecture, we may say here that the dispersal and rearrangement of faunæ and floræ in past ages of the world, have been powerfully affected by geologic changes; as, for example, the effects produced by the glacial period as a whole, as well as those profounder changes—the upheavals, depressions and submergences of continental margins and areas. It must be borne well in mind that at the present time the faunæ and floræ of the various zoögeographic regions are continuously but gradually undergoing many changes, brought about by the extermination of some forms, by the slow development of new species, and by the gradual physical changes of the earth characteristic of the present epoch.

To sum them up, we may say, in the words of Huxley: "It has been discovered by careful comparison of local faunæ and floræ that certain areas of the earth's surface are inhabited by groups of animals and plants which are not found elsewhere, and which thus characterize each of these areas."

We are now in position to return to the naming of those areas, and as we have already said, the views of Mr. Wal-

lace will receive our attention in the premises. It was in 1876 when Wallace published the work containing his scheme, and he then recognized six primary zoögeographical regions of the globe, and subdivided them as follows:

I. Palæarctic region, with four sub-regions: (1) North Europe. (2) Mediterranean, or South Europe. (3) Siberia. (4) Manchuria, or Japan.

II. Ethiopian region, with four sub-regions: (1) East Africa. (2) West Africa. (3) South Africa. (4) Madagascar.

III. Oriental region, with four sub-regions: (1) Hindostan, or Central India. (2) Ceylon. (3) Indo-China, or Himalayas. (4) Indo-Malaya.

IV. Australian region, with four sub-regions: (1) Austro-Malaya. (2) Australia. (3) Polynesia. (4) New Zealand.

V. Neotropical region, with four sub-regions: (1) Chili, or South Temperate America. (2) Brazil. (3) Mexico, or Tropical North America. (4) Antilles.

VI. Nearctic region, with four sub-regions: (1) California. (2) Rocky Mountains. (3) Alleganies, or East United States: (4) Canada.

As has already been intimated, these regions are practically independent of the question of the marine distribution of animals. But the principles which apply to zoö-oceanic areas and regions are, in the main, almost identical with those laws which govern the occurrence of the life-forms in the terrestrial zoögeographical divisions. So that, for our present purpose, they need not be especially discussed here.

With respect to the terrestrial divisions just given, and using Mr. Wallace's own words, we are to note that the "I. Palæarctic Region, which includes all Europe to the Azores and Iceland, all temperate Asia from the high Himalayas and west of the Indus, with Japan, and China from Ningpo and to the north of the watershed of the Yang-tse-Kiang; also North Africa and Arabia, to about the line of the tropic of Cancer. This may be popularly called the European region, Europe being the richest and most varied portion of it and containing representatives of all the more important types; but it must not be forgotten that the region includes a much larger area in Asia, and that there are many peculiar North Asiatic animals.

"II. The Ethiopian Region, which includes all Africa south of the tropic of Cancer, as well as the southern

part of Arabia, with Madagascar and the adjacent islands. It may be popularly termed the African region.

"III. The Oriental region, which is comparatively small, including India and Ceylon, the Indo-Chinese countries and southern China, and the Malay Archipelago as far as the Phillipines, Borneo and Java. It may be popularly called the South Asiatic or Indian region.

"IV. The Australian Region, which is composed of the remainder of the Malay Archipelago, Australia, New Zealand, and all the tropical islands of the Pacific, as far east as the Marquesas and the Low Archipelago.

"V. The Neotropical Region, which comprises the whole of South America and the adjacent islands, the West Indies or Antilles, and the tropical parts of Central America and Mexico. It may be well called the South American Region.

"VI. The Nearctic Region, which consists of all temperate and arctic North America, with Greenland, and is thus well described as the North American Region."

As it has just been defined, it will be seen that extensive areas of the Palæarctic Region are under a high state of cultivation and much of it is thickly populated. In consequence of these two facts extermination, in times past, has been the fate of many of its mammalia, and this process is at present going on more rapidly than ever. It has thinned the ranks of animal life within the boundaries of the region to such an extent that, notwithstanding its extensiveness, it ranks at present below the smaller old and new world regions of the tropics in the richness of its mammalian fauna. Some of its forms, however, are quite peculiar, while others are highly characteristic. There are camels and a half-dozen different genera of deer. A genus of dogs of the family *Canidæ* occur, and a great variety of the rodentia abound, as rats, mice, squirrels, hares, and their kind. Seven genera of ruminants fall within the limits of this region; all of the family *Bovidæ;* and weasels and pandas are also characteristic. Upon its northern coasts are found seals, and the land carnivora are well represented in the wildcats, the wolves, foxes and bears. In other parts wild horses and asses exist, the latter being abundant in Asia.

Passing to the Ethiopian Region, which includes in the main Africa and the great island of Madagascar, we are struck at once with the marked differences in its mammalian fauna as compared with what we found in the Palæarctic Region. Madagascar and the Mascarene Islands are especially remarkable, and in the case of the

first mentioned we find many characteristic small mammals not found on the African Continent, while it lacks all the large carnivora, the apes, giraffes, elephants, antelopes and others which are found there. Wallace has said:

"The African Continent is preëminently the country of large mammalia. It possesses an abundance of elephants, rhinoceroses of several species, giraffes (now peculiar to it), gorillas and baboons—the largest of the ape tribe—a host of large and remarkable antelopes, the huge hippopotamus, several species of zebras, wild buffaloes, several remarkable forms of swine, and an abundance of lions, leopards, and hyenas—forming together an assemblage of large and highly organized animals such as occur nowhere else upon the globe. There are also many smaller, but very remarkable forms."

And so it goes with the four remaining regions defined above, the Oriental, the Australian, the Neotropical, and the Nearctic. Each possesses its peculiar and characteristic forms of mammals, and each region its varying physical aspect. What has been said of the first two holds true in principle in all the others.

Australia of the Australian Region is especially characterized, inasmuch as all the more ordinary forms of mammals are not found there, their room being taken by the varied group of the marsupials, of which there are 5 distinct families and many genera. *Echidna* and *Ornithorhynchus*, two other distinct families of most remarkable mammals, are also found on the Australian Continent.

Thus we see how it is that animal and plant life is distributed over the face of the globe according to certain natural laws, and that those distributions have varied during the past history of the earth, owing to the varied application of the same laws and to other circumstances. In short there is in the individual case of any existing animal or plant on the earth a reason for its being found over one area and not over another. There is a very good reason why giraffes are found in Africa and not in Mexico, as there is why we find yucca in the heart of Mexico, and not in Africa.

Science has made very considerable progress toward the elucidation and demonstration of many of the laws to which I refer; there still remains, however, in the grasp of the great unknown a vast store of facts not yet brought to light, though the incessant investigation of the scientific researcher tends to almost daily pass them over to the realm of the known.

With this brief but, I believe, sufficient account of animal distribution for our present purpose, we are now in position to pass a step still nearer the main subject of our lecture. For, without some strong hint as to the laws governing the distribution of existing life, we could hardly have been expected to draw a clear picture of what geology has to show us for the ages that are past.

As commonly defined in books, geology is the science which treats of the physical history of the earth's crust, and of the operation of those laws which are responsible for the changes which have occurred in it throughout time. But there is a great deal more in the science than this definition would at first appear to indicate, and in the writer's estimation no one among us has more beautifully dwelt upon its real teachings than our distinguished countryman, Professor Joseph Le Conte.

Le Conte has pointed out that the study of the science of geology falls naturally under three great divisional heads or departments. Under structural geology we may regard the earth much in the same light as the anatomist regards the body, and study it from the standpoint of its external form and internal structure. Or, again, under dynamical geology we may have to do with what may be considered the physiology of the earth, or the action upon its structure by the elements, as the air, water and certain chemical and physical forces. Lastly, we have historical geology, comparable with the science of embryology for it takes into consideration the history of the development of the earth and the laws which have governed that development.

Our authority, then, proceeds to show "that there are certain laws underlying all development—certain general principles common to all history, whether of the individual, the race, or the earth." The geologist finds that these general principles are quite as applicable to his science, or to the earth's history, as they are, for example, to the civic history of man, or the history of civilization.

"All history is divided into eras, ages, periods, epochs, separated from each other more or less trenchantly by great events producing great changes. In written history these are treated according to their importance, in separate volumes, or separate chapters, sections, etc. So earth history is similarly divided into geological eras, ages, periods, etc.; and these have been recorded by Nature in separate rock-systems, rock-series, rock-formations, and rock-strata."

When such comparisons receive our further reflections it becomes apparent that eras, ages, periods, etc., in all history insensibly graduate into each other, "though sometimes the change is more rapid and revolutionary." We may even make it comparable with individual history, where those ages we call infancy, childhood, youth, and manhood imperceptibly merge into each other. And here, not infrequently, some deeply felt experience may hasten on the characteristics of the succeeding stages. Certain vicissitudes make some individuals men of affairs before they are twenty, yet they may retain some of those characters which pertain to youth.

"In social and political life, too, successive phases of civilization, embodying successive dominant principles, usually graduate into each other; yet great events have sometimes determined exceptionally rapid changes in the direction or the rate of movement. So also is it in geological history. The eras, periods, etc., usually shade more or less insensibly into each other; yet there have been times of comparatively rapid or revolutionary change. In all history there are periods of comparative quiet, during which forces of change are gathering strength, separated by periods of more rapid change, during which the accumulated forces produce conspicuous effects."

Geologic history teaches us that early in the earth's growth there was a time when those organisms we call mollusks were the dominant types throughout nature. It was an age of mollusks. They appeared gradually and gradually culminated, then declined, then imperceptibly became less and less numerous, to exist in diminishing numbers up to the present time. As they began to decline a higher group, or the fishes appeared, which passed through a similar rise, culmination and declination, and again carried up in a similar manner to the present age. Corresponding ages of reptiles and mammals, successively follow overlapping and merging with each other in precisely the same manner and each in turn successively dominating, thus giving us an age of mollusks, an age of fishes, and age of reptiles and so on. Here, as in individual, or in social history, or the history of civilization, we find each overlapping age foreshadowing the previous one and the dominating characteristics of each arising in the successive ages of their predecessors. When these phases are made comparable with individual history, Le Conte reminds us; "In youth, the characteristic

faculties of childhood, viz., perception and memory, decline and become subordinate to the higher faculty of imagination, and this, in turn, becomes subordinate to the still higher faculty of productive thought; and thus the whole organism becomes higher and more complex. Each stage of development including not only its own characteristic, but also, in a subordinate degree, those of all preceding stages."

□ Precisely the same principles apply to social development, where the forces characteristic of the previous stages of its history are successively absorbed and included by each succeeding stage. And, as development proceeds, the entire social structure ever becomes more complex, richer in detail, and occupies higher and higher planes. All this is repeated in geologic history.

Now in geology there are two methods employed for determining the extent of its eras, ages, periods and other divisions. We may, in the first instance, rely upon the unconformity of the rock-system, and in the second in the change of the life-system. Almost without exception the life-system is found to correspond with the unconformity of the rock-system, and in the few cases where it does not it should be followed as the safer guide.

All over the world the great geologic eras, ages and periods are the same, though the minor divisions of the latter are non-cotemporaneous they are, nevertheless, likewise similar.

First, then, we have the grand divisions of the earth's geologic history as a whole. These are designated as the eras and there are five of them. The oldest of all is the Arcnæan or Eozoic, which includes the Laurentian system; above this occurs the Palæozoic era, embodying the Palæozoic or Primary system; superimposed upon tnis is the Mesozoic era, the record of which is embodied in the Secondary system this is followed by the Cenozoic era, whose history has been written in the Tertiary and Quarternary systems; fifthly and lastly occurs the Psychozoic era, which may well be designated as the era of mind, it being the recent system or the system of the present time.

So again, as has already been intimated, the history of the earth as a whole is susceptible of being divided into seven ages, based upon the culminations during geologic time of certain great groups of animals. These are, first, the Archæan age which is measured by the rocks of the Laurentian system; second, the age of mollusks, or the age of invertebrates, including the Silurian formation of

rocks; the Devonian age, represented by the series of rocks in which the ichthyian or fish forms culminated; the age of Amphibians, represented by the rocks of the carboniferous strata; the age of Reptiles, represented by the rocks of the Secondary system; the Mammalian age, represented by the Tertiary and Quarternary; and lastly, the age of Man, represented by the recent rocks.

Unconformity in the rock system, though of a less general nature, also furnishes the necessary basis for the subdivisions of eras and ages into the minor subdivisions of periods and epochs. So much, then, for the methods adopted by geologists for demonstrating the natural divisions of the earth's crust and the names they have applied to those divisions. The subject includes a very small part of the science of geology—one chapter out of a great many, many others—but it will suffice our purpose here. It will hardly be necessary to add that the Laurentian rock system of the Archæan era is the oldest known to geologists, the others in the order we have presented them being successively more and more recent until we arrive at the Psychozoic or the present horizon.

It is not to be believed, however, that the very lowest stratum of the Laurentian rocks represents the original or primitive crust of the earth, for there is evidence in them of stratification which abundantly indicates that they have been formed from other rocks which underlie them, and these likely from still others and vastly older ones of which we as yet have no definite knowledge. When one appreciates the manner in which these rocks were built up, and realizes the fact that in some parts of the world they exhibit a thickness of 40,000 feet, it is not difficult to conceive of the enormous lapse of time they represent. As a matter of fact the Archæan era extends over a greater length of time than all of the remaining history of the earth put together. We have all heard, at differ nt times, of the enormous periods of time that geologists insist upon when speaking of the processes that have led to the formation of the crust of the earth as it is now presented to us. It will be quite in point in this place to dwell for a moment upon this matter, as it is of importance in connection with what I have to say further along. There are those who believe, though it is a satisfaction to know that their number is steadily decreasing, that geologists are prone to indulge in a species of guessing when they come to estimate the lapses of time that have taken place during the various eras, ages, periods, etc., of the world's history, as recorded in the

several geological horizons. Some have gone so far as to say that they have been guided simply by the great apparent age of the fossil remains of animals that formerly inhabited the earth; that the mere fact of such remains being converted into petrifactions must of necessity have taken millions of years; that those estimates are, in their estimation, still further supported by the discovery in different parts of the world of entire forests of enormous trees which at some other very remote age were similarly fossilized. But those people to whom I refer are quite wrong in the premises, and the conception of the lapses of time in the world's history, as arrived at by the geologist, is by no means based upon any such data. Nor do we claim upon the other hand that the time calculations as arrived at by the geologist are to be considered correct beyond all peradventure of a doubt; they may be hundreds of years or even thousands of years wide of the truth; but, notwithstanding all that, they never vitiate his right to state within certain bounds the immense lapses of time that it has taken Nature to bring about some of her results as they are revealed to us in our study of the physical history of the world and recorded in her geology.

In order to illustrate my meaning permit me to present you with one or two examples. A very simple one is the calculation of the time it has probably taken for the Niagara River to excavate its gorge. That feat is but one of many thousands of Nature's chiselings, which has been accomplished entirely within the scope of the present epoch, and the computation of the time it has taken to perform it is a matter of no great difficulty, as the physical factors of the problem are at our hand. The geologist tells us that he believes it to have been about 36,000 years. Now there is no difficulty in ascertaining the fact that Lake Erie has an elevation of about 300 feet above Lake Ontario, the former being terminated by an abrupt escarpment of about 300 feet in height; and, from this point, according to an eminent authority, "a narrow gorge, with nearly perpendicular sides and 200 to 300 feet deep, runs backward through the higher or Erie plateau as far as the falls. The Niagara River runs out of Lake Erie and upon the Erie plateau as far as the falls, then pitches 167 feet perpendicularly, and then runs in the gorge for seven miles to Queenstown where it emerges on the Ontario plateau. Long observation has proved that the position of the fall is not stationary, but slowly recedes at a rate which has been variously estimated

from one to three feet *per annum*. The process of recession has been carefully observed, and the reason why it maintains its perpendicularity is very clear. The surface rock of Erie plateau is a firm limestone. Beneath this is a softer shale. This softer rock is rapidly eroded by the force of the falling water, and leaves the harder limestone, projecting as tablerocks. From time to time these projecting tables are loosened and fall into the chasm below." Taking into consideration the configuration of the country; the nature of the strata and their contents of the walls of the gorge; the carefully observed progress of erosion, which has been noted for many years by competent persons; it soon becomes evident to any intelligent observer that, in the first place, the falls of Niagara were originally situated at Queenstown, and that during the present geologic epoch they have cut their way back seven miles to their present position, and that this erosion is advancing at a rate of about one foot *per annum*.

With the length and height of the gorge, and with the rate of the recession of the falls each year, by the simplest arithmetic we can easily get at the result we have already mentioned. In the history of the formation of the world, however, 36,000 years is an exceedingly small matter, really but a moment as compared with a century when we consider it in connection with the absolutely inconceivable lapses of time recorded in the older geologic eras. How insignificant, for instance, as compared with those typical and vast erosions as seen in the Grand Cañon of the Colorado and other cañons of the same enormous system. The plateau in which that great erosion occurs is elevated some seven or eight thousand feet above the sea; and, in case of the Grand Cañon of the Colorado, the eroding stream it contains has cut its way down through the earth for a distance of from three to nearly seven thousand feet in some places. It has a length of 300 miles. Its lateral walls clearly exhibit nearly the entire geological series from the tertiary age downward, and it shows the strata of the eroded plateau to be very nearly horizontally deposed. There is not a shadow of a doubt as to how that great abyss was sculpt, for the same agencies are still in operation at the present moment and the enormous eroding power can be seen as the work goes on. If the comparatively short and shallow gorge of the Niagara River took 36,000 years to be carved back to its present site, I beg to leave it to your

imagination how long it took the Colorado River to find its present bed, a mile below the surface of the earth, and for a distance of 300 miles in length.

Deltas of rivers and their formations furnish us with more of Nature's operations from which we may make tolerably correct estimates of the time it takes for such feats to be performed. The delta of the Mississippi could not have taken less than 50,000 years and probably took a very much greater time to form. Here we have for data the cubical contents of the delta; the annual mud-discharge of the river; and the computation of the extent of the submarine portion of the delta, and some few minor factors.

Again, the history of the coal beds and the accumulation of coal offer us with another series of facts from which it is possible to gain some idea from another point of view of the enormous lapse of time it has taken Nature to achieve some of her works.

It is now perfectly demonstrable that coal was accumulated during the Carboniferous period, and the accumulation and formation of it took place at the mouths of certain great rivers, which at that time discharged themselves into the ocean. There, in such places, existed vast peat swamps, overgrown by the peculiar vegetation of that period, which at all times were subject to floods from the river on the one hand, and inundations from high oceanic tides on the other. A recent coal bed, of identically the same nature, is now in the process of formation under our very eyes in the Mississippi delta, and careful study is alone required to decide the rate at which coal is deposited therein. Other forces are and were also at work both during recent time and during the geologic period or subperiods of the Carboniferous system. These have been scientifically considered by many competent geologists, and their operations taken duly into consideration, but it is not necessary for us to dwell upon them here, and to many of you they are no doubt already familiar. It has been ascertained, for example, that a vigorous vegetation yields by death and decay and growth about 100 tons of dried organic matter per century to the acre. But such an amount of vegetable matter pressed to the specific gravity of coal would make a layer only a little over half an inch in thickness, when spread over the area just mentioned. It must not be forgotten, however, that certain chemical losses are experienced during such a process, and upon giving these due weight the result has been arrived at that, instead of de-

positing over half an inch, our estimate should read only about one-eighth of an inch, at which rate it would require about ten thousand years to make a layer one foot thick. In any coal basin with an aggregate thickness of 100 feet its formation must have required one million years to accomplish. But it is not uncommon to find 150 feet to be the average thickness in some coal measures, and a proportionately longer time must have been required. This method of computation takes into consideration the rate at which a vigorous vegetation produces organic matter, but we may also arrive at a solution by estimating the rate at which the river deposits its sediments over the area in which the coal is forming.

I will conclude this part of my subject with an example of this nature, presented us by the authority quoted in several instances above, and we are told that our indebtedness is to Sir Charles Lyell for the "estimate of the time necessary to accumulate the Nova Scotia coal measures. This coal-field is selected because the evidences of river sediments are very clear throughout. The area of this coal-basin is 18,000 square miles; but the identity in character of portions now widely separated by seas—e. g., on Prince Edward's Island, Cape Breton, Magdalen Island, etc.—plainly shows that all these are parts of one original field, which could not have been less than 36,000 square miles.

"At Pictou, the thickness is nearly 13,000 feet, and we certainly shall not err on the side of excess, therefore, if we take the average thickness over the whole area of 7,500 feet. This would give the cubic contents of the original delta deposit as about 51,000 cubic miles. Now, the Mississippi River, according to Humphrey and Abbott, carries to its delta annually sediment enough to cover a square mile 268 feet deep, or nearly exactly one-twentieth of a cubic mile. Therefore, to accumulate the mass of sediment mentioned above would take the Mississippi about 1,000,000 years."

And, mark you, in the geological series of the earth's crust the Carboniferous period is not more than one-thirtieth of her recorded history. Then we must believe that that history covers a period of 30,000,000 of years. But Mr. Wallace, by a most careful estimate made from the premises of the general erosion of the land area of the earth, makes its recorded history but 28,000,000 of years. Here is a difference of 2,000,000 of years, as well as a difference of opinion, but it can, nevertheless, hardly

be considered worthy of dispute. To me, the most remarkable part of the whole question is that so many fair and candid men, using such a variety of physical data, should, in reality, arrive at such a comparatively uniform result after all.

Yet 30,000,000 of years "gives us no adequate conception of the time involved in the geological history of the earth. For rocks disintegrated into soils and deposited as sediments are again reconsolidated into rocks, lifted into land-surfaces to be again disintegrated into soils, transported and deposited as sediments. And thus the same materials have been worked over and over again, perhaps many times. Thus the history of the earth, recorded in stratified rocks, stretches out in apparently endless vista. And still beyond this, beyond the recorded history, is the infinite unknown abyss of the unrecorded. The domain of geology is nothing less than (to us) inconceivable or infinite time." (Le Conte.)

With the brief sketch I have given of the distribution of existing animals, and the still briefer account of the divisions of geologic history and the enormous lapses of time that measure those immense ages, we may now proceed to show that it is through the science of palæontology that biology is linked to the very important science of geology.

Broadly speaking, palæontology treats of the fossil remains of animals and plants as they occur in the earth's crust. It takes into consideration their structure, their taxonomy, their affinities both with extinct types and forms yet existing. Moreover palæontology is the handmaiden of geology, inasmuch as it is through its aid, or the employment of the life-system, we are enabled to determine and limit the several eras, ages, periods, etc., in geology. In this sense it acts as a check upon the alternative method of establishing the divisions in geology, of which we speak, or of the employment of the rock-system to which reference has already been made.

As I have said in a previous lecture one of the great departments of palæontology is palæobotany, the science that deals with the fossil floræ of the world; and in another, though less strict sense, the science of archæology in reality falls within the domain of palæontology, as in the main it treats of the works of extinct races of men. My reasons have already been advanced for including palæontology, palæobotany. and archæology, all within the limits of the science of biology where in reality they each and all belong.

It is most natural that that department of palæontology which takes into consideration the geological history of man is the one that has always been of the greatest interest to the world at large. For some time past our knowledge of the history of man in its entirety has been sufficiently extensive so as to admit of its being systematically arranged under various heads and divisions. Students in archæology see three main divisions or ages, as they are called, in the history of human progress and civilization. These are first the Stone age including that lapse of time when men employed stone principally to form their tools and weapons. Early in his history such material was simply chipped out to serve his purpose, and that time is referred to as the Palæolithic period; but during the latter part of the stone age men came to polish those chipped stone implements, and that time has been designated as the Neolithic period. The Palæolithic period has again been subdivided into a Reindeer age, corresponding with the second Glacial epoch, and a Mammoth age, corresponding with the Champlain epoch. With the Neolithic commences the present Psychozoic era, and the reign of man is completely established. These ages, however, are not universally represented, nor do they everywhere, by any means, closely correspond with the geological horizons I have mentioned. This will be clear when we come to think that it is only three hundred years ago that our Indians were in the Stone age, and the South Sea Islanders have, as yet, progressed no farther than the Neolithic period to-day. It is in Europe that the correspondences are the closest, for it is due to the archæologists of that country to have first clearly established them.

Our two remaining ages in the history of human civilization are the age of Bronze and the Iron age, but their consideration falls completely within the pale of modern history, and so does not especially concern us here.

Every year that goes by rewards the researches of the archæologist in various parts of the world with the discovery of relics which tend to throw more or less light upon the history of primeval man upon earth. For the most part these consist either of examples of his ancient works or of the remains of man himself. And, we may add here, that notwithstanding the fact that the evidence on the side of the question of man having arisen in time from the most lowly ancestors, by evolutional development, it is, nevertheless, true that up to the present time all the remains we have of him go to show that nothing

as yet has been discovered but what shows him to have been most distinctively human. Those remains of the earliest men yet met with attest to the fact, to be sure, that he stood very low in the scale of civilization, and had by no means attained to the position of the "lord of creation." What I mean to say is that we have not as yet met with the skeletal remains of fossil or sub-fossil man, that directly link him with his anthropoid affines. Such material, I am constrained to believe, lies locked up for the archæologist of the future in the Quarternary of Asia, where most probablv primitive man originallv arose.

There is no doubt whatever that man existed throughout the entire Quarternary period. In this country his remains have been found upon both coasts; his first appearance was, however, probably upon the Pacific Coast and, as many believe, as a migrant from Asia. His bones and rude works of art have also been discovered in Europe, India and South America. Such relics often occur in caves, in the drift and elsewhere, where they are mixed up with the bones of animals long since extinct, as mastodons, cave-bears and the like, leaving no doubt whatever as to the cotemporaneity of the two. In Southern France occur the Perigord Caves, in which have been discovered some of the most interesting specimens of extinct men; pieces of reindeer antler have been discovered, upon which, plainly etched, we find figures of the mammoth long, long since exterminated in Europe. Several skulls of early or middle Quarternary men have been found in different parts of Europe, and that, too, in situations precluding all doubt as to their age. These skulls present every evidence that they belonged to a very, very low species of man. There are plenty of men living, however, and they are to be found among the savage races, in whose skulls we see characters quite as low as those distinguishing the crania of the men of the early Quarternary period. Nevertheless, it must be remembered that all the skulls of ancient men thus far discovered are of the very lowest of the savage type. It is fair to presume that they in their way indicate what kind of men existed in those far distant times, and that we will never meet with any higher types coming from the same geological horizon. If we do ever meet with any at all different, everything points to the probability that they will prove to be of a very much lower order, most likely anthropoid in their general contour. So much for the Quarternary, now what do we find as we pass to the Tertiary age; nothing more than one would naturally

expect, that is, a greater meagerness of the record. No remains of bones of ancient men, and only a handful, comparatively speaking, of somewhat doubtful specimens of his works. These are principally roughly chipped flints, and bones of animals showing some suspicious scratches; and, in truth, such is the evidence in brief. Writing in 1883, Le Conte remarks: "The Miocene man is not acknowledged by a single careful geologist." * * * * * "Mr. Favre, reviewing the whole subject up to 1870, and, again, Evans, President of the Geological Society of London, reviewing the subject up to 1875, and Dawkins in 1879, and Lubbock in 1881, decide that the existence of Tertiary man is yet unproved."

For myself I can only say, and influenced as I am by the study of a large collection of fossils from the Pliocene of Oregon, only recently completed, that my inclinations lead me to believe that man did exist during the latter part of the Tertiary, at least, and was probably in existence as a very low type of the genus *Homo* at a much earlier date. As to how long man has existed upon earth as man, geologists are at variance in their opinions, the time ranging all the way from 7,000 to 100,000 years. Evidence is not lacking, I think, to show that the latter is probably more nearly true than the former. Researches in this most engaging field of all others open to man, are being continually pushed with the greatest degree of interest, and there can be no question that in the future many important discoveries will be made, tending to throw additional light upon the subject.

It is nought to be surprised at, that the geological history of man is so thoroughly imperfect, and were it not for his works that have been preserved in different parts of the earth, how vastly more imperfect that record would be! Remove all that the archæologist has brought to light; bring down the palæontological history of man to his bones alone, and it would be represented but by a few mutilated pages in a history of many, many volumes. He would then be comparable with other forms of vertebrates of the great group of mammals to which he belongs, and how meager, very meager, is the geological record with some of them. Thousands upon thousands of mammals, with histories extending through enormous lapses of time, have existed, developed and become extinct upon the earth, and absolutely left no palæontological history at all. Many of those animals were undoubtedly of mas-

todonic proportions; legions of them were of moderate and diminutive sizes; and their forms must have been almost of endless variety. Think for a moment, as an illustration of my meaning, of the innumerable herds of buffaloes that once covered our Western prairies; and what, do you suppose, would be the chance of discovering a fossil specimen of that animal a few thousand years hence? Barely any whatever. Wallace tells us:

"Fossil remains of land animals are, of course, rarely found except in lacustrine or estuarine deposits; and these are often entirely wanting throughout extensive geological formations. But even where such fossiliferous beds occur, the conditions favorable to the preservation of small mammalia are exceedingly rare, the entire series of freshwater Wealden beds having yielded no trace of them, although we are quite certain that they were then both varied and abundant. Even more remarkable is the fact that the whole twenty-five species of Purbeck mammals, belonging to ten genera, were obtained from a single stratum only a few inches thick, and from an area of less than 500 square yards. Yet these small animals must have abounded at this period; and it is impossible to believe that anything but a most imperfect and fractional representation of the mammalian fauna of the country could have been gathered into this narrow graveyard. But this thin stratum occurs amid a mass of freshwater deposits 160 feet thick, the whole of which have been thoroughly and systematically examined by the officers of the Geological Survey of Great Britain; and though many of the layers contain remains of land organisms—plants, insects, and land-shells—no other part of the whole series has yielded a single fragment of mammalian remains! Having the striking example of the worthlessness of negative evidence, it behooves us to be cautious of rejecting any legitimate conclusions from the facts in our possession, on account of the absence of the direct evidence of fossil remains."

From this let us turn to the other aspect of the question and examine what in reality palæontologists have discovered and the bearings of that material upon biology. Confessedly as meager as the number of fossils of animals is that have come to light, it is so only when taken in comparison with the vast host of extinct forms which have as yet not rewarded the researches of science, and still are hidden in the crust of the earth, or have perished utterly. For, take mammals as an example, the list of fossil forms now known is by no means to be de-

spised, and the light their careful study has thrown upon many problems touching the origin of their kind is simply incalculable. Many hundreds of them are in our possession, and the number is constantly being added to each year. Bearing in mind what has already been said relative to the geographical distribution of existing mammals, what would we naturally look for among the fossil forms of the present geological era in any given locality? Naturally, the fossil and sub-fossil specimens of the existing mammals of that locality; and do we find them? It is exactly what we do find, and the fossilized bones as they are discovered are ascertained to have belonged to individuals of identically the same species of those now living, or in the case of the extinct types to very closely related species, genera, families and so on. In other words, all over the world the fossil floræ and faunæ of the Recent epoch of the Psychozoic era are of species still living over the regions where such material is discovered.

To some extent this is also characteristic of the next preceding geologic system or of the Quarternary; but, and still adhering to the mammalia as our example, we meet with some very remarkable differences. Now it is a well-known fact that during the Quarternary period, in all the high-latitude regions, the earth's crust experienced many profound oscillations which were accompanied by great climatic changes. Mammals, as a class, culminated during those times, and the pristine types of men appeared early on the scene. The geologic history of the world passed through the Glacial, Champlain and Terrace epochs During the first the earth's crust, everywhere in high latitudes, was elevated to a height of 2,000 feet or more above its present level. This area was sheeted over with a great mantle of ice, which sloped away far down into the temperate zone. An arctic climate prevailed. The reverse movement took place during the Champlain epoch and the entire region was again depressed, and that to such an extent that the seas stood upward of a 1,000 feet above their present levels. Lastly, the Terrace epoch was characterized by the whole region to which we refer gradually coming to assume its present physical aspects. So there was, during this time, a gradual rising of the land of the high latitudes, accompanied by a gradual approach to our present climate. Many of the events and profound physical changes enacted during those three epochs have been carefully worked out, and in detail,

but the great length of their account renders it impossible for me to enter upon such an extensive subject here.

In this country we find the fossil or preserved remains of mammals that flourished during the Quarternary period in, first, marshes and bogs, where the heavier herbivores were frequently mired; secondly, in the bone caves where the carnivorous types most often occur, together with the other large species as ungulates, rodents and edentates. Lastly, many various species have been discovered in the river gravels, especially in those of California. Most of the Quarternary mammals are now extinct; they were notably peculiar and often of great size. Some were the direct ancestors of the mammalian types that now exist; others had run their race and passed away without leaving any descendants. Great mastodons and elephants roamed over various parts of what is now the United States. Superb specimens of these most perfectly preserved in their skeletal structure, have been taken in New Jersey, New York and elsewhere. In one locality in Kentucky over one hundred skeletons of mastodons were obtained. Enormous bisons or buffaloes also existed over the same areas, together with ponderous beavers and gigantic horses. A great lion also roamed over the same region, as did also a great elk, much exceeding in size our now-existing elk of the Rocky Mountains. Many other very remarkable forms also flourished, making together a list of far too great length for enumeration in the present connection.

Passing down rapidly next through the Tertiary system of the Cenozoic age, we discover that the first mammals of all arose at its dawn. They came in immense numbers, in swarms, indicating that the revolutions then going on on the earth gave rise to a marked rapidity of change in the varied representatives of that group. During those times climates were adjusting themselves; enormous and extensive migration of species was going on; and as a result thereof an extinction of all those forms which could not withstand the commingling of the various geographical faunæ. Herbivorous animals predominate but others are not wanting, and a vast array of orders and species ranged over the central portion of this country. Lemurne monkeys were even to be seen, though the earlier forms of men had apparently not yet made their appearance. Indeed it is the mid-regions of the United States, and in the freshwater basins there found that we find the very richest deposits wherein occur the fullest records of the mammalian faunæ of the Cenozoic

age in America. In the bad lands of Nebraska, for instance, have been discovered the fossil remains of tigers, camels, rodents, hyenas, panthers, wolf, deer, horses, rhineros, and a variety of more generalized forms.

But among the main points to be remembered about all those mammals of the Tertiary system is, that they arose from small, non-placental forms which flourished during the latter half of the Meozoic age, and that those forms were in many ways yet intimately affined with birds and reptiles. Reptile, indeed, was the main stem, and from it branched off during the Triassic the bird and mammal stock, and the linking types were to be found upon every hand. Passing through the enormous lapse of time represented by the Cretaceans of Mesozoic, and successively through the Eocene, Miocene and Pliocene of the Tertiary, we find in the several parts of the United States, at least, that from those small generalized types were produced the ancestors of the more modern mammalian forms, a number of which have already been given above. Among other remarkable forms there existed, for example, in the Pliocene of the Niobrara Basin of our Bad Land territory, several species of horses, one of which was only two feet high; camels of ancient type, and it is now recognized that both horse and camel originated upon this continent and not in the Orient as most naturally suppose to be the case. As many of these early mammals evolved, there was a gradual increase of the brain-mass in many of the species; an elaboration of other structures, as the teeth and feet; and a general tendency toward the establishment of modern types. Indeed, in all Nature there is no more engaging chapter in palæontology than the great lesson taught by the specimens, and specimens in abundance, showing the evolvement in time of our modern horse as it has passed from the eohippus of the Eocene, an animal no bigger than a fox, with its four-toed feet in front and its three-toed feet behind, and with its simple tooth-structure, through the orohippus of the Middle Eocene; the mesohippus of the Lower Miocene; the miohippus of the Miocene; and so on up to recent time where we have the horses of the present day. The gradual structural changes are perfect, and the shad'ng from one series of fossil skeletal remains to the next succeeding species is quite as imperceptible as it is marvelous. And yet how widely separated are the extremes, and what enormous lapses of time does the entire process represent. Cope has traced, by means of similar material, the development of the American

camels in the same manner; and it is a most extraordinary picture when we come to study the clearness with which this fossil material will permit us to trace the branching stocks of oxen, deer, antelopes, hogs, and their allies, or the ungulates as they are known, from the generalized common root-stock, the amblypoda, to their modern forms. Other mammalian groups have been worked out in the same way, as far as our discoveries will admit, and doubtless in the future many of the gaps will be filled in, and that is one of the most remarkable chapters in the study of such remains, for the kinships of each new species as it comes to light can be either very closely guessed at, or its affinities are so strikingly apparent, at first glance, as to admit of no manner of doubt in the minds of all biologists.

It is important to remember, in connection with this, that America, as was the case in other parts of the world, passed through many remarkable physical revolutions during the Tertiary age. In Cretaceous time, or just before the Tertiary, it is known that this country was divided into two great continents separated by a vast and shallow sea covering all that area now familiar to us as the Western Plains and Plateau region. Subsequently mid-continental upheaval took place and this cretaceous sea became slowly obliterated, and the two aforesaid continents joined each other. The tertiary period is now inaugurated by the Eocene epoch, (and the shading of the one into the other, that is, the Mesozoic and Cenozoic was most gradual), during which time great freshwater lakes existed in certain parts of the West, which during the Eocene were drained by continental upheaval. Later Miocene lakes were formed by a corresponding depression over the region of the plains, and still later, toward the close of the same period, the entire coast chain of mountains of the Pacific Coast were formed by an uprising and folding of the sea bottom. Other enormous changes took place, and an authority at my hand states: "That from the end of the Cretaceous to the end of the Tertiary there was a gradual upheaval of the whole western half of the continent, by which the axis, or lowest line, of the great interior continental basin was transferred more and more eastward to its present position, the Mississippi River. Probably, correlative with this upheaval of the western half of the continent was the down sinking of the Mid-Pacific bottom, indicated by coral reefs. Also as a consequence of the same upheaval the erosive power of the

rivers was greatly increased, and thus were formed those deep cañons in the regions (New Mexico, Colorado and Arizona), where the elevation was greatest. Thus the down sinking of the Mid-Pacific bottom, the bodily upheaval of the Pacific side of the continent, and the down cutting of the river channels into those wonderful cañons are closely connected with each other."

It must not be understood that these vast depressions and upheavals of great areas of territory were performed in a rapid manner, for they required ages for their completion; indeed, in several parts of the earth very much the same thing is going on under the very eye of science. The coast of Norway, for example, is now rising at an average rate of two and a half feet per century. Let that continue for 1,000 centuries, and you may easily understand what I mean by a geologic upheaval of a land area. Still those great revolutions, notwithstanding the gradualness of their performance, did powerfully affect in time the various faunæ of the country, and greatly influenced mammalian migration. In numerous instances those migrations have been carefully worked out and traced, traced as the several mammalian faunæ influenced by one cause or another passed from one part of a continent to adjacent land areas. Those changes in the habitats of entire groups of mammals went on in obedience to certain ever-acting natural laws, for thousands upon thousands of years, down to the present day. Many types, as we have seen, became utterly extinct; others by a slow evolution have left descendants in no way resembling their original ancestors, while as a whole the entire host of the world's mammalian faunæ has led up through those untold ages to quite perfectly explain the laws of animal distribution as I have sketched them for you to-day, and to thoroughly account for the presence in various parts of the earth of the animals as tney now exist there. And, one other very important thing must be noted, and it is that mammals, as has been the case with most all other organized forms, since their first appearance on the earth have passed from types of a highly generalized structure, by evolution, to their descendants of modern times wherein the structure is seen to be far more highly specialized. This passage from the simpler anatomical forms of mammals, all of which are now extinct, to the more highly specialized types of the existing faunæ, has taken almost inconceivable ages of time.

What has just been said about the evolution of the

mammalia is, with equal truth, applicable to the entire history of organic life upon the globe, from its very beginning as far back as we have been enabled to trace it down to the present instant. Our knowledge of the life-system of the earliest Archæan time is exceedingly meager, but when we come to examine the old primordial beaches of the Silurian epochs we meet with fossil forms that are the representatives of the faunæ which figured at or very near the dawn of life upon earth. They are the primordial ancestors of all the main branches of animals, except vertebrates, which are to be found in recent times. They are the earliest, structurally the simplest, remains known to the biologist. They are the elements from which Nature has built up the vast number of complicated organisms of our own era, and it is easily demonstrable that it was many millions of years ago that they existed. And yet, even this more or less varied fauna of Silurian time must have been derived from still simpler forms, the history of which reaches far, far back into the vast unknown—the unwritten pages of geologic record.

By an overwhelming number of facts, then, biologists of our own and of past times have demonstrated beyond all manner of doubt that the distribution of all animals in space, or in other words the existing world's faunæ, is in accordance with certain known laws, and that distribution is wholly explained by the distribution of all animals that have existed in time; or in other words the extinct world's faunæ which, in turn, were also distributed over the various regions of the earth in accordance with laws, also largely known to us, are essentially the same as those laws which account for the modern distribution of organic life. One of the most philosophic living thinkers in biology tersely paragraphed our knowledge upon this point when he said:

"So long as each species of organism was supposed to have had an independent origin, the place it occupied on the earth's surface or the epoch where it first appeared had little significance. It was, indeed, perceived that the organization and constitution of each animal or plant must be adapted to the physical conditions in which it was placed; but this consideration only accounted for a few of the broader features of distribution, while the great body of the facts, their countless anomalies and curious details remained wholly inexplicable. But the theory of evolution and gradual development of organic

forms by descent and variation completely changes the aspect of the question, and invests the facts of distribution with special importance. The time when a group or a species first appeared, the place of its origin and the area it now occupies upon the earth, become essential portions of the history of the universe.

"The course of study initiated and so largely developed by Mr. Darwin has now shown us the marvelous interdependence of every part of nature. Not only is each organism necessarily related to and affected by all things, living and dead, that surround it, but every detail of form and structure, of color, food, and habits, must—it is now held—have been developed in harmony with, and to a great extent as a result of, the organic and inorganic environments. Distribution becomes, therefore, as essential a part of the science of life as anatomy or physiology. It shows us, as it were, the form and structure of the life of the world considered as one vast organism, and it enables us to comprehend, however imperfectly, the processes of development and variation during past ages which have resulted in the actual state of things.

"It thus affords one of the best tests of the truth of our theories of development; because the countless facts presented by the distribution of living things in present and past time must be explicable in accordance with any true theory, or, at least, must never directly contradict it." (Wallace, Art. Distribution, Brit. Encyclop., 9th Ed. V. VII, p. 267.)

These truths, so well expressed, go far toward explaining the relation that the science of biology bears to the science of geology, for it clearly shows that it is chiefly through the interdependent biologic science of palæontology. At the dawn of life the earliest organisms were of forms most simple, and from them grew a mighty tree with myriads of branches, limbs and twigs, and as these became differentiated during enormous stretches of time they produced, in the majority of cases, groups of organisms which were more and more specialized and complex in structure. So that during the almost inconceivable lapse of time representing earth's physical history, branches of this great tree have gradually produced such remarkably specialized groups of beings, as modern teleostean fishes, modern reptiles, modern birds, modern mammals, and, as a family of the latter, modern men.

The terminal twiglets of this vast organic growth and

its branching life-descent are now seen in the living faunæ existing upon the surface of the world of our day, or teeming in our oceans and inland waters. Palæontology, the science of the organic forms of the past, imperceptibly merges into zoölogy, the science of the organic forms now in existence. And, this growth has never been checked for an instant; the same laws are now in operation as have been in operation throughout all geologic times and ages; many animals now in existence are doomed to utter extinction, some in the near future, others in ages to come. A host of others will send down into futurity their descendants, and from them will undoubtedly arise, in time, new forms to furnish the world with still different species, in many cases totally unlike their nowaday ancestors, as those ancestors, the species now with us, are totally unlike the forms from which they in turn were derived. Even the topographical physical aspects of the world itself must change, as many, many of those changes are now gradually going on and are well known to science; their contemplation, and careful study, and comparison with the happenings of past ages, which in so many instances are so clearly written upon Nature's historic pages, form one of the very grandest fields of research open to the intellectual activity of the mind of man.

III.

Its Value as a Study.

We have seen in the first two lectures of the present course what a very wide field of inquiry the science of biology is now considered to cover. Indeed, any one of its four main divisions of morphology, distribution, physiology or ætiology constitutes a vast science in itself. We saw how morphology dealt with the entire structure, both gross and minute, of all animal and plant forms as well as the relation of those structures to each other in the organism. And, when we come to think of the organic complexity of the great majority of the myriads of different animals now living upon the earth, such a task, alone, as unraveling their various plans of structure would at first sight appear to be the labor of untold ages for an infinite number of minds and hands. This undoubtedly would be the case were it not for the fact—a fact long since known to biologists—that throughout the entire series of animal forms and throughout the entire series of plant forms, both living and extinct in either case, and from the most simple type to the most complex, there prevails the same fundamental uniformity in the plan of structure. We may, for example, select any convenient form from the animal series, as a rabbit or a cat, and after we have made a complete study of its entire structure we have the key that unlocks the history of the whole. From the cat, for instance, we may ascend the scale, step by step, through the higher types, to include man himself, and it will be found that in the skeletons of all the bones are identically the same and require but a common descriptive nomenclature. The viscera and organs of the body are comparable throughout. The arteries, veins, nerves and lymphatics in a cat, a lemur, an ape and in man are strictly comparable, morphologically, and perform identically the same functions. There are upward of 150 pairs of muscles or more in a cat, all of which have been carefully described and named, yet

the corresponding ones pertain to the physical organization of man, and no change in their nomenclature is demanded.

And so we might pass on through the entire anatomy of these several types; but this is not all, for we may bring to bear all our most delicate instruments of precision, and by the aid of the microscope and chemical reagents reduce the body of a cat, or any of the other forms mentioned, to their ultimate elements, and the very morphological units—the cells—are the same in a cat as they are in a man; the same in a lemur as they are in an ape; the same in an ape as they are in a cat.

But, as we are all aware, the matter has not been allowed to rest here, for the development of all these types has been carefully studied; and in tracing this back in man, in the cat, in the ape and the rest, we come to a stage in each where the forms presented to us are quite indistinguishable. One cannot help being impressed by the expression of wonder seen in the face of him who, for the first time, views accurate drawings of a tortoise, a chicken, a dog, and a man, at the fourth week of their development. It requires the eye of a thoroughly practiced investigator to tell the one from the other, you may be well assured; for at that stage the tail even offers no distinction and is quite as well developed in man as it is in a dog. Carrying our investigations still further in this matter of development we are led to the fact that all animals have their origin in the simple cell.

"Moreover," as Huxley tells us, "the investigations of the last three-quarters of a century have proved that similar inquiries, carried out through all the different kinds of animals which are met with in Nature, will lead us, not in one straight series but by many roads, step by step, gradation by gradation, from man at the summit to specks of animated jelly at the bottom of the series. So that the idea of Leibnitz and of Bonnet, that animals form a great scale of being, in which there are a series of gradations from the most complicated form to the lowest and simplest; that idea, though not exactly in the form in which it was propounded by those philosophers, turns out to be substantially correct. More than this, when biologists pursue their investigations into the vegetable world, they find that they can, in the same way, follow cut the structure of the plant, from the most gigantic and complicated trees down through a similar series of gradations until they arrive at specks of ani-

mated jelly, which they are puzzled to distinguish from those specks which they reached by the animal road."

This great truth, so clearly stated by Huxley, no doubt likewise expresses what has been the manner of growth and development of plants and animals in the history of the earth. No one who has properly examined the evidence can now doubt for a moment that in the beginning of the world the primitive material from which all animals and plants have since arisen was the absolutely organless protoplasm. In other words we may say that the history of the origin, growth and development of all living forms in time is epitomized in the history of the origin, growth and development of existing plants and animals; just as the history of the origin, growth and development of any individual species of animal is an epitome of the history of the origin, growth and development of the tribe to which that species belongs.

Passing to physiology, another one of our main divisions of biology, we find all that holds true of structure also holds true of the functions of the structures; and, in the higher or more complex types of animals the functions performed by the organs are complicated, but as we study them in passing down the series we find they become gradually more and more simple in their performance. Even the mental faculties form no exception to this rule, for notwithstanding the marvelous workings of the mind and the brain in the highest types of man, those faculties can be traced down through the animal series until at last we meet with their very rudiments as performed by the brains of the lowest forms of animal life. It was the distinguished British biologist, Mr. George J. Romanes, who said in an admirable article published some six or seven years ago in the North American Review:

"After centuries of intellectual conquest in all regions of the phenomenal universe, man has at last begun to find that he may apply in a new and most unexpected manner the adage of antiquity, 'know thyself.' For he has begun to perceive a strong probability, if not an actual certainty, that his own living nature is identical in kind with the nature of all other life, and that even the most amazing side of that nature—nay, the most amazing of all things within the reach of his knowledge, the human mind itself—is but the topmost inflorescence of one mighty growth whose roots and stem and many branches are sunk in the abyss of planetary time."

I have never been in sympathy with those observers who would draw hard and fast lines, the lines of instinct

and of reason, between the lower forms of animal life on the one hand and man on the other. For, I believe, as great and as evident as the gap is which separates the manifestations of the mental faculties of the very lowest types of humanity and the very highest types of those vertebrates next in order to them is simply a difference of degree and not of kind.

We have also seen, in a former lecture, how the study of another primary branch of biology, or the question of distribution, explains the laws which govern the dispersal of animals and plants over the face of the globe and in the great bodies of water of the earth, not only for existing faunæ, but for the vast faunæ that have existed since life first appeared in the world, and which are now for the most part extinct.

Finally, in the fourth division of the science of biology, or that is in ætiology, we saw how from the consideration of the facts of the science we passed to the task of determining the causes of those facts. It is now thoroughly appreciated that biological phenomena can be explained, in so far as our present knowledge will permit, by considering the causes as simply special cases of general physical laws. There is no question dealt with under the head of ætiology of greater importance than the investigation of the origin of living matter, and upon entering that field we meet with one group of investigators who still adhere to the theory of *abiogenesis*, or what in reality is the old theory of spontaneous generation, and another group who are the supporters of the biogenetic view, which contends that all living beings have been derived from pre-existing forms of life. This latter is termed the theory of *biogenesis*. Very close reasoning is done upon both sides, but at the bottom of it all it cannot be said that we are in possession of any positive knowledge upon the subject. Still, I believe it lies within the pale of attainable knowledge, and is a problem that will be satisfactorily solved by the biologists of the future.

With this brief recapitulation of the scope of biology before us, we now may ask of what value, as a study, does this great science, this comprehensive department of human knowledge offer to mankind at large? To properly answer this it will be necessary to say a few words upon the question as to wherein lies the value of the pursuit of any study, and apply our finding to the pursuit of the study of biology. With respect to any of the sciences, my opinion has always been that the discoveries of truths

and facts constitute the most important, the most practical and the most noble field into which men can throw their best mental and physical energies. History has long ago proved that however apparently a present-day-discovered fact may seem to be of utter worthlessness, owing to its non-applicability to utilitarian ends, such facts invariably come into the very best play in the hands of succeeding generations. Thousands upon thousands of examples might be cited to sustain this statement, drawing them from every department of human knowledge. The only thing demanded is that the discovery be a real truth, a living fact. Such discovered facts have often lain idle for a generation or more when, owing to later discoveries of, perhaps, a related kind, they at last are brought into use with amazing power, and frequently prove to be of lasting value and worth to all humanity.

Now, for more than a century past, the most extraordinary thing about the discovery of biological facts is that in the vast majority of instances, comparatively speaking, they so rapidly come to meet some utilitarian end in one or another line of human pursuits.

In the first place very often the discovery of a new fact in biology has the tendency to eradicate some wrong idea and replace that wrong idea by the right one. The first may have been entertained for ages, by men all over the world, and have been the source of much bad practice and, perhaps, of downright misery to generations of people. No one for an instant will question the utility and importance of this, inasmuch as ideas rule the world and it is of the highest import that those ideas should be the correct ones. In short the world can only be made happy when truth prevails, and the foundations of all our theories of things, all our practices and all our ideas are governed by truth and fact.

To instance my meaning, human history offers no better example, as a whole, than the contest that has been going on for ages between man, upon the one hand, and the entire category of diseases and injuries to which his organism is subject, upon the other. In the early history of medicine and in the early history of humanity, hosts upon hosts of men, women and children perished from diseases, during every generation, from the sheer lack of knowledge on the part of their fellows of what was the correct thing to do for them. But what was worse than all this, when men calling themselves physicians essayed during those times to combat the results of injuries or

the ravages of disease in their fellows, such was the nature of their knowledge and the meagerness of its amount, that in the vast majority of cases the would-be helper was a far greater danger to the sufferer than the disease with which he was afflicted. In truth, it may be stated, that in the day to which I refer the gentlemen of the medical profession were responsible for the destruction of the lives of a greater number of people than was disease itself. The reason is not far to seek, for the constitutions of those attacked by disease had not only to contend with that disease, but, in addition thereto, with the medical man who came to cure them. This is not surprising when we come to think how limited was the then knowledge of the laws of sanitation; of the real causes of many of the infectious maladies; and, finally, which is the more important of all, the prevalence of the most erroneous ideas of both the science of anatomy and the science of physiology.

Since those times biology has grown apace, and both medicine and surgery or, I may say, the profession of medicine in its entirety, has felt the remarkable advances made along the lines I have just indicated. Not only has medicine favorably felt the nature of those advances, but in that most important and practical field of human endeavor, has been clearly shown the value of biological study. Through such studies alone, it has been proven beyond all manner of doubt that infectious disorders are caused by living organisms, and by combating them, in one way or another, those disorders may be either cured or prevented altogether. An ever increasing knowledge of the structure and physiology of all animals, both high and low in the scale of organization, has, moreover, allowed pathologists to trace, in some instances, the more complicated forms of disease in men to their rudimentary phases in the lower animals. It is clear that by such processes we will in time be enabled to arrive at a complete history and knowledge of many of the affections of the various structures of our bodies. And this has come about by the ever increasing biological investigations into the anatomy and physiology of all forms of animal life. Not only have such biological studies been of the greatest importance to man in the way of his own personal welfare, comfort and happiness, but they have extended to his material belongings, for the possession of such increased knowledge has been of the most unlimited service in the treatment of the infectious disorders and the surgical injuries to which all the domesticated animals

are liable. Moreover, the investigations in those fields have again reacted, and to the end of still further elucidating a number of the more complex problems in human pathology. Surely there is no one among us to-day who for a moment doubts the value of the biological researches that are now almost hourly being made upon the structure and life-histories of myriads of germs that cause disease; or of the value of the labors of the world's corps of patient biologists who are continually engaged in furnishing us with a fuller understanding of the morphology and physiology of those structures which those many species of germs are prone to attack. Such studies are most assuredly fraught with results of great practical value, and are of the very highest importance. Justice to this subject could hardly be attained to in an entire course of lectures, and the interesting field it covers is reflected in an extremely rich and varied literature.

Again, the value of the most exhaustive researches in general morphology can hardly be questioned; for, in the first place, as I have just shown, they not only have the great practical value of elucidating the more obscure points in man's own organization, but through the enormous array of facts arrived at, biologists have been enabled to fix beyond all peradventure of a doubt the position man occupies in Nature and his true relation to the universe at large. This has had the effect of completely exploding that old traditional notion, that ancient myth, the embodiment of the idea that man constituted the great central figure in Nature, and held a position altogether peculiar; that structurally, physiologically, mentally and psychologically he was completely disassociated from all the rest of the living forms of this world; indeed, that he was hardly of this world at all, but was to be considered as simply a being existing here only temporarily and but very remotely related to any and all things of earth, upon which he had but recently come and upon which his race expected to sojourn as probationers but a comparatively brief time; and, finally, what was more or quite as erroneous as all the rest of this strange traditional notion put together, that, somehow or other, he thus being apart from Nature all the rest of the world had been especially created either for his personal benefit; or as affording him an array of natural objects for hi especial amusement; or for, as I say, a temporary abiding place, tastefully fitted up, to answer as a habitation during his brief sojourn upon the earth. Biological research

has here most conclusively shown, whether it be tasteful for us to face the truth and the facts in the premises or not, that not a single factor in this old traditional notion, which has been told to so many of us, has the slightest semblance to verity to recommend it. Biological research has given us the true relation that man bears to Nature, and has most clearly demonstrated where his place is there. For it has shown that no such things exist in Nature as what may be called "central figures," and man's position in the universe is no more peculiar than is the representative of any other family of the class to which he belongs—that is, the class mammalia. Outside of his own family man is both structurally and physiologically most closely linked to those mammalian forms in the group next below him, or to the anthropoids.

After making a comparison of all the minutest details of structure, it was Professor St. George Mivart who was compelled to admit that: "Viewed from the anatomical standpoint, man is but one species of the order Primates; and he even differs far less from the higher apes than do these latter from the inferior forms of the order." (Less. in Elem. Anat., p. 496.) Further, biological research has shown that all of the various groups of existing men, from the very lowest racial types to the highest and best representatives, are quite of this world and form just as much a part of its history as any other factor composing the realm of nature. There is no valid evidence to show that his stay upon the earth is to be a temporary one, and a great deal of very excellent biological evidence to show that he has existed here for a great many thousands of years. And as to all the rest of Nature having been especially created for his benefit and pleasure, I can only say that it is hardly necessary for me, in this day and generation, to adduce the simple arguments required to prove the absurdity of any such notion. Every page in the history of man, since the day he first was enabled to make record of his earthly career, reeks with pain, with misery and with unhappiness. Man has had to contend with the elements just as fiercely as other living organisms of the world; he has had to contend even far more strenuously against the ravages of disease and accident; all over the world Nature presents the majority of mankind with objects that are anything but pleasurable for his beholding; and, finally, for I will not multiply the many examples that could easily be brought forward, men are even so constituted that they continually war upon each other and by so doing offer thousands of

spectacles to the more peaceful side of society that can hardly be designated as pleasurable or beneficial ones in Nature's drama.

Yet, in face of all this, science has emphasized what must be patent to any thinking mind, and that is, apart from the similarity of his anatomical structure as compared with other mammals there is at least one thing that widely separates man from all else in living Nature. But its teachings are also to be found in one of the volumes devoted to biology, viz., in the science of psychology. From the psychical point of view the vast abyss that separates man from all the rest of living creation is so wide and so profound that there can be but little danger in overestimating either its width or its profundity. Speaking of this aspect of the question it has been said that: "Man must be set off not only against the animal kingdom but against the whole of Nature besides, are an equivalent: Nature the book—the revelation—and man the interpreter."

"So in the history of the earth; from one point of view the era of man is not equivalent to an era, nor to an age, not to a period, nor even to an epoch. But from another point of view it is the equivalent of the whole geological history of the earth besides. For the history of the earth finds its consummation, and its interpreter, and its significance in man." (Leconte.)

Not to weary you, I should like to adduce another example wherein the value of biological study has been most abundantly proved within a comraratively short space of time. It is perfectly safe to say that within the last half century the entire theory of agriculture has been completely revolutionized. From the crudest notions and ideas, as they were put into practice by the tillers of the soil both in this country and in Europe during the early part of the present century, agriculture has grown to occupy a place among the sciences. This has come about through the marvelous advances made in our knowledge of physiological botany; in the pathology and morphology of plants generally, and the principles applied to those cultivated by the agriculturist. To the vast store of facts that have been discovered bearing upon general entomology, and in particular to the study of the life histories of that enormous host of species of insects which are either beneficial or injurious to garden vegetables, fruit trees, grains, cultivated shrubs and the like. In similar directions even knowledge of another kind is coming into play, and our own Depart-

ment of Agriculture here is vigorously pursuing a line of study that in the future must surely have its use for the agriculturist. This is nothing less than the pursuance of a systematic investigation of the contents of the stomachs of all our species of United States birds at all seasons of the year. The object here aimed at is to encourage the protection and presence of those species of birds which are ascertained to destroy those insects which are known agricultural pests; and, on the other hand, to either drive away or destroy those species which prove by their habits or food to be injurious in any way to the success of the agriculturalist. Such a field of research has been termed a Department of Economic Ornithology, and of course demands a scientific and practical application of the facts brought to light by the biologist. Agriculture is usually made to include the care, breeding and study of the domesticated animals; and the recent improvements and successes along such lines are entirely due to the researches of the biologists, for they have come about through a fuller knowledge of the morphology of animals, the physiology of animals, of the diseases to which they are liable and the nature of the parasites which infest them; and of the laws pertaining to artificial selection in breeding, and kindred matters.

Once more, and it is familiar to most of us, the excellent results that have rewarded the efforts of our National Fish Commission. Here is a scientific body interested in the protection, propagation and extension of our food fishes, oysters and the like, and it almost goes without the saying that their successes depend upon the proper application of the knowledge of the facts discovered by the icthyologist of the habits, foods, and general economy of the enormous list of species of our fresh and salt water fishes. And, so far as the oyster is concerned, certain biologists have well-nigh devoted their life's work to its complete study, and the practical economist has not been slow in seizing upon the results of his researches and turning them to practical account.

Finally, it may in truth be said that our studies in the direction of the structure and physiology of all forms of plant and animal life cannot be in any way too exhaustive, for the results attained are sure, sooner or later, to come powerfully into play to the furtherance of the best of human interests, and it is hard to say more than this. To the same end our material progress is furthered in certain fields, in proportion as we come in possession of a full knowledge of the geographical distribution, the

habits, the various foods and the life-histories of all animals, all living organisms, whatsoever, as well as everything possible to be known of plant life both in space and in time. Everything is to be gained by a vigorous pushing of the study of both normal and pathological histology in every possible direction, by which we mean an attainment of a knowledge of the intimate structure of the tissues in every living organism, both animal and vegetable, and the various diseases which may affect the same.

Did my time but admit of it it would, in a similar manner, not be difficult for me to show that the most valuable and practical results are sure to follow in the wake of our increased knowledge of such other biological sciences as palæontology, ætiology, sociology and psychology.

Many have been the triumphs of biology in the past, and in many departments of science and learning; but, as great as those have been, I am constrained to believe that still greater ones are to be met and dealt with in the future. Many of the grander conquests I have already referred to or in some degree explained. These are mainly the elucidation and establishment of an infinite number of facts forming a basis upon which is safely reared the doctrine of the theory of descent of all animal and plant forms, both in space and in time. Second, the revealing of the fact that a uniform and fundamental plan of structure pervades all Nature, and as depending thereon we find that the same holds true with regard to function. Thirdly, that the present distribution of animal and plant forms over all parts of the earth are most perfectly explained by the far-reaching researches that biology has accomplished in palæontology. Lastly, the invaluable results that have rewarded biological investigators in the fields of comparative psychology and sociology.

These having been some of the major achievements of the science, I desir , for the purpose I have in view, to simply recall to your memories some of the more interesting facts that biology has brought to light, as incidental to the main laws just enumerated. They all most powerfully tend to establish the value of biological research, both as a study from a purely utilitarian point of view, and as a most efficient adjunct to the proper training of the human intellect.

For a long time morphologists, in their dissections of all manner of plants and animals, met with structures

which came to be called "rudimentary organs," but more properly known now as "vestigial structures" or organs. As examples of these we may cite the teeth in the upper jaw in the embryos of many of the ruminating animals—as in the case of the embryos of our common cattle. These teeth never fully develop, are functionless and of absolutely no importance to the animal. Teeth also occur in the jaws of young whales that have a similar history, for as we know in the adult whale the jaws only support the baleen or whalebone, and the fœtal teeth in them entirely disappear, never having had any physiological importance.

Quite a long list of similar vestigial structures occur in every man, woman and child among us, and it was utterly impossible to make out the purpose of their being there until biology stepped in to render the proper explanation. Among birds we find, in one species or another, rudimentary wings incapable of being used in flight, and in most all ordinary birds a vestigial thumb in the hand. Snakes have a rudimentary lung, and rudimentary *mammæ* occur among the males of the mammalia. In some lizards the vestigial limbs and the skeletal arches that support them are entirely concealed from superficial view by the skin covering the body; this is also the case with the hind limbs in a whale. Plants everywhere offer us hundreds of like examples. Plenty of cases of rudimentary and sightless eyes occur in various species, which now pass their existence underground. But the name of these structures is legion, and scarcely a living organism exists that offers us not one or more examples, so it is quite out of the question to give the list, *in extenso*, of them here, and as for that instances enough have already been cited.

Of these vestigial organs, Mr. Darwin has said that: "By whatever steps they may have been degraded into their present useless condition are the record of a former state of things, and have been retained solely through the power of inheritance. We can understand, on the genealogical view of classification, how it is that systematists, in placing organisms in their proper places in the natural system, have often found rudimentary parts as useful as or even sometimes more useful than parts of high physiological importance. Rudimentary organs may be compared with the letters in a word, still retained in the spelling but become useless in the pronunciation, but which serve as a clew for its derivation. On the view of descent with modification, we may conclude that the

existence of organs in a rudimentary, imperfect and useless condition, or quite aborted, far from presenting a strange difficulty, as they assuredly do on the old doctrine of creation, might even have been anticipated in accordance with the views here explained." (Origin of Species, p. 402.)

Another magnificent array of interesting and most important facts have been brought to light in the course of the innumerable researches that have led to the discovery that all our domesticated animals, as pigeons, the various tame fowls, cattle, dogs, horses and cats have all been derived from wild types, each within the group to which it severally belongs. Darwin proved, after years of patient and most scientifically conducted experiments upon the very richest kind of material obtainable in all the world, that all the vast list of varieties of domesticated pigeons were derived from a single wild species—or from the common blue rock-pigeon, *Columba livia*, the primary stock. In a similar manner have all the remarkable forms of domesticated rabbits been traced back to the common wild rabbit, which has proved to be the original primary species from which they were all undoubtedly derived. Many of the domesticated species of rabbits are now so utterly different, both in internal structure and external form, that they are more widely separated, morphologically, from the common wild type than the latter is from any other wild species in any part of the world.

Illustrating this point in another way, a distinguished German naturalist says: "In the year 1419, a few rabbits, born on board ship of a tame Spanish rabbit, were put on the island of Porto Santo, near Madeira. These little animals, there being no beasts of prey, in a short time increased so enormously that they became a pest to the country, and even compelled a colony to remove from the island. They still inhabit the island in great numbers; but in the course of four hundred and fifty years they have developed into a quite peculiar variety—or, if you will have it, into a "good species"—which is distinguished by a peculiar color, a rat-like shape, small size, nocturnal life, and extraordinary wildness." (Haeckel.) It is most important to note now, however, that this new species (*L. huxleyi*) will not cross with specimens of the original European domesticated stock, and in one or two instances where they have they are infertile, thus proving that they are thoroughly differentiated as a species.

When in the West, a number of years ago, and often in the camps of our Sioux Indians, I found it in many instances difficult to distinguish their dogs from the wild prairie wolf or coyote from which undoubtedly all were derived originally. In some cases, however, the better differentiated species were quite distinct and very different appearing animals. The parent stock of all our remarkable breeds of chickens is beyond all doubt the ordinary wild chicken of India, the *Gallus bankiva* of ornithologists; and, personally, I satisfied myself of this fact, not long ago, by a most careful comparison of the entire structure of alcoholic specimens of the India species sent me from India for the very purpose, with numerous species of our common fowls, comparing the skeletons and structure for structure throughout. Among the domesticated species the game fowls come nearest the original wild parent stock, and yet, in appearance, what a wide gap exists between them, for instance, and the extraordinary Polish cocks. In comparing our common tame turkey, anatomically, with a fine series of the wild turkeys which I had collected for the purpose, I not only satisfied myself that our domesticated form was derived from the wild one, but I succeeded in obtaining a series of skeletons which showed all the striking differences in beautiful serial arrangement, standing as they did between the two extremes.

I might go on citing such cases by the hour, and multiply the examples in an endless variety, but enough has been presented to show what biology is bringing out along the lines given. The literature in such fields is now simply enormous, and the study of the entire question of hybrids, artificial selection, interbreeding, sterility, and the production of new species and subspecies, is not only fraught with great value but it has had the effect of being of the most incalculable benefit to the breeder of domestic stock of all kinds, as well as throwing a powerful light upon the entire question of the doctrine of descent and the origin of species as we find them in Nature. Why, when Darwin wrote his two volumes, on "Animals and Plants under Domestication," they were used more by the scientific agriculturists and breeders the world over, for the practical and useful information they contained, than they were by the opponents of the theory of descent to study the arguments set forth in them, in their endeavors to defeat the same —and this is saying a great deal.

There are several other very beautiful laws presented

on the part of Nature, the operations of which are still but imperfectly known to the biologist, and to these we can but barely allude. There are the several phases of the general law of correlations, as exemplified in many ways both on the part of animals and of plants; of the laws of the relations existing between organisms, on the one hand, and all that goes to the make-up climate on the other; of the laws of protective resemblances among animals and plants; of parthenogenesis and other peculiar forms of reproduction; of the laws of variation, and the effects of use and disuse of organs; of the laws of the extinction of species, and of persistent types of animals; and some few others which show those delicate compensations, equilibriums and balancings that are ever in operation throughout all Nature and of which we yet have so very imperfect a knowledge. Still, to some extent, we have been enabled to arrange and classify those laws, and these classifications will become more perfect as the examples they present become better understood. Upon every hand, however, cause and effect are seen to be unceasingly in action, and ever with an absolutely unvarying exactitude whatever may be the nature or class of cases wherein it is seen. The balancements are sustained everywhere with a precision admitting of no variation whatever; all cells moving in harmony at all instants of time, and in obedience to uncompromising laws. No field could be more inviting to the biologist for his investigations and his meditations, as a few examples which I select from various biological authorities will go far toward showing.

A number of years ago I had under my observation a man that possessed six fingers upon either hand, and he had several sisters and a brother exhibiting the same monstrosity. In some of the cases, however, but one hand showed it; and a brother in the family had normal hands. Only one of this man's parents, his father, I think, showed the condition, and in all the number of toes on the feet were normal. In such cases the numeral relation of the toes and fingers vary, but if a six-fingered and six-toed man should marry a woman exhibiting the same digital characters, and propagation were to be kept up for generations by pure inbreeding the character would become permanently established and result in a special race of such people. Haeckel says: "In a Spanish family, each child except the youngest had the number six on both hands and feet; the youngest, only, had the usual number on both

hands and feet, and the six-fingered father of the child refused to recognize the last one as his own." I must let an example of this kind stand as a representation of the thousand and one other characters that are inherited by children from their ancestors in every part of the world. Indeed, this matter of inheritance in so very common, both in the case of normal characters as well as abnormal ones or even in diseases or the predisposition to the same, also habits and traits, that they are scarcely noticed in our everyday life. All animals and plants exhibit the same tendency, and instead of it being a matter of light import the entire law is one of the very greatest biological importance, and has been dealt with under the general law of heredity and inheritance; the first having reference to the power of transmission and the latter to actual transmission. These when taken in connection with the now well-proved fact of the mutability af organisms, it at once becomes apparent to any one of us how important it is to well examine and study the resulting phenomena. This applies especially to the biologist, and to the scientific and thoughtful physician.

Connected with this law we have to deal with another, or the one referring to the question of the alternation of generations, where inherited characters are known toskip one or more generations; and this law, pushed to the extreme, explains the matter of reversion or atavism. An excellent illustrative example of the last are those cases wherein we sometimes see a horse born with series of distinct stripes of black arranged in a definite way on the body and limbs. No such character ever occurred in its ancesters so far as they can be traced back, and the condition can alone be explained by atavism, or in other words the original stock of all of the horses from which such an individual is descended was a striped animal or a striped race or family, something like the now wild zebras, quaggas, etc.—existing horse-like animals in Nature. In ages to come such cases of atavism will undoubtedly, and not unfrequently, arise through intermarriage of the hybrid descendants among us of Ethiopian and Caucasian stock. One has but to study in this city the very numerous and extremely light-colored hybrids of Afro-Caucasian species which are now annually making their appearance to understand this. In fact, I have collected one good example of this for use in my anthropological studies. A man of undoubted Saxon descent married a woman as white as himself, and whose ancestors had been white for a generation or two before

her, very likely for a longer time. Their first child was as black as the veriest Congo that ever was born. When we come to consider that hybridization between the two races has been going on since the earliest days of slavery in this country, and bringing our knowledge of the laws of inheritance to our aid, especially the atavistic phase of them, such a case needs no particular explanation at the present time.

Still another law, or the law of sexual transmission, offers many curious cases; that is where one of the sexes suddenly exhibits a character or characters which normally only belong to the opposite one. Under this we find those peculiar examples of women having full beards and mustachios; does among deer, with fully developed antlers; hens wearing the spurs of the cock; and hundreds of other most remarkable cases to which I forbear to allude at the present time. They are phenomena of great importance to the biologist in his studies of the operation of natural laws.

Even the question of hybridism has a literature and a broad field of study of its own to-day. Examples of this are common all over the world and in many quarters are receiving the most exact investigation possible, which its high importance so fully deserves.

Some half a dozen other laws have been carefully differentiated and elucidated by the biologists, and an endless series of examples occur upon all hands in Nature to fully illustrate them. The whole question of adaptation also presents us with its numerous well-defined laws, and their exemplification in the animal and vegetable worlds. Their comprehension is absolutely essential to the student who would understand the operations daily being enacted in the natural world about him, on every hand, by every form of living organism.

For the present, however, we cannot enter further into these fields, and at the most I feel I have brought ample evidence before you wherewith to prove the undoubted value that attaches to the study of the biological sciences.

This being so, the very practical question next arises, or questions I may say, of, first, to whom should biology be taught; when and where should that instruction be given; and what are the best methods for imparting the necessary knowledge of the science. To these several inquiries I would answer that I would make its main principles and laws, its essential truths, a prerequisite to the examination of every accepted teacher for a public school throughout the United States, in order that it

might be properly taught in all our public schools; similarly it should be entered into the scheme of education of every private school, college and university throughout the land; a very complete course in biology most assuredly should form a part of the curriculum of every authorized medical college in America; and finally, it should reach the people through public lectures, public museums, zoölogical gardens, and public libraries and laboratories.

At the outstart, it may be said, in general terms, that the means to be employed in teaching biology consist in the handling and proper examination of biological material. To this end we employ dissections of existing organisms; histological researches with the microscopes and other instruments of precision; next, the making of drawings and sketches of the objects we have observed and studied; then, physiological studies, wherein will come vivisections, various contrivances to exhibit the fundamental principles of the science; and the application of the abiological sciences of chemistry and physics. We employ all manner of illustrative specimens; as biological material in alcohol, models of all descriptions, the skins of animals preserved in the various ways, diagrams of all kinds—both of natural size and enlarged—colored or uncolored, also palæontological material, together with full series of geological and physical charts exhibiting the distribution of plants and animals both in space and in time. The literature of biology is to be freely used, and a very important part of the instruction depends upon lectures, the museums, collections of animals and plants, and the zoölogical gardens.

As to the general methods to be adopted in biological study, Mr. Huxley presents us with some excellent advice when he says: "Since biology is a physical science, the methods of studying it must needs be analogous to that which is followed in the other physical sciences. It has now long been recognized that, if a man wishes to be a chemist it is not only necessary that he should read chemical books and attend chemical lectures, but that he should actually perform the fundamental experiments in the laboratory for himself, and thus learn exactly what the words which he finds in his books and hears from his teachers mean."

"If he does not do so, he may read till the crack of doom, but he will never know much about chemistry. That is what every chemist will tell you, and the physi-

cist will do the same for his branch of science. The great changes and improvements in physical and chemical scientific education which have taken place of late have all resulted from the combination of practical teaching with the reading of books and with the hearing of lectures. The same thing is true in biology. Nobody will ever know anything about biology except in a *dilettante* 'paper-philosopher' way, who contents himself with reading books on botany, zoölogy and the like; and the reason of this is simple and easy to understand. It is that all language is merely symbolical of the things of which it treats; the more complicated the things, the more bare is the symbol and the more its verbal definition requires to be supplemented by the information derived directly from the handling, and the seeing and the touching of the thing symbolized; that is really what is at the bottom of the whole matter. It is plain common sense, as all truth, in the long run, is only common sense clarified. If you want a man to be a tea merchant, you don't tell him to read books about China or about tea, but you put him into a tea merchant's office where he has the handling, the smelling and the tasting of teas. Without the sort of knowledge which can be gained only in this practical way his exploits as a tea merchant will soon come to a bankrupt termination. The 'paper-philosophers' are under the delusion that physical science can be mastered as literary accomplishments are acquired, but unfortunately it is not so. You may read any quantity of books, and you may be almost as ignorant as you were at starting if you don't have, at the back of your minds, the change for words in definite images which can only be acquired through the operation of your observing faculties on the phenomena of Nature."

The preliminary methods of procedure in biological study here pointed out by Professor Huxley were given to a New York audience by him as long ago as 1876, but those methods have been true for all time and are especially applicable in these days. Indeed researches conducted in precisely the manner pointed out by the most distinguished expounder of biological science we have living, the author whom I have just quoted, have come to be spoken of by everyone who has the progress of human learning at heart as the "scientific method." Now to me, the modern "scientific method" in any kind of investigation or research means nothing more than, first, having one thoroughly acquaint himself with all of

importance that has previously been written upon the subject, or matter, or organism he proposes to examine; next, to make that examination as carefully as possible, and as thoroughly comparative as his material will admit, bringing to his aid the various modern instruments of precision used by biologists or other scientists in their own departments, and, finally, also summoning to his assistance a clear knowledge of those natural laws as they are at present understood and have bearing upon the question in hand. To complete any such investigation it should be printed, free from error, and in some medium where it will become easily available for the students of the future, and show upon every page, plate, and figure of the record that its author had carried out in detail every suggestion that I have just presented; that he has properly accredited former workers in the same fields with such facts as their prior labors revealed; that he is candid, clear, thorough, logical, and guided by the desire to discover only the truth in every detail to which he has directed his mind during the task he has set himself to perform.

It goes without the saying that the principal field demanding the attention of the biologist is that one which takes into consideration the life-histories, morphology, and physiology of all living animal organisms and plants. Such studies are chiefly made in the biological laboratories, the museums, and the zoölogical gardens, the former always being properly fitted up with the proper appliances and text-books for that kind of research.

Remembering now what has been said on the question of the fundamental uniformity of structure, as exemplified in the animal and vegetable kingdoms, it will at once be appreciated that it obviates the necessity of the student in zoölogy studying separately each and all the entire series of species representing the existing world's fauna on the one hand, and her flora on the other. We can easily see how impossible such a task would be of accomplishment, inasmuch as there are considerably over 100,000 insects alone, and the species of plants in the world is simply enormous. Fortunately, and taking insects for example, which we have just mentioned, we have such things as what may be regarded as more or less type-forms in all the great groups of animals and plants, and by making a proper selection of one of these among the insects, and mastering all that can be known of its life-history, structure, and so forth, it is quite possible to gain a very fair conception of the correspond-

ing facts as they are presented on the part of the vast majority of insects. With a definite knowledge of that much at his command, and especially a comprehension of the nomenclature used in the description of the various structural parts, the student will find that the transition to the study of those modifications in the anatomy of other insect forms is natural and not difficult, so that by the study of a comparatively few more well-chosen specimens he soon acquires a wide understanding of the whole, and is capable of comprehending the most of what he reads in his text-books on the subject.

In a similar manner one may master the life-histories, the morphology and physiology of a number of well-selected specimens or types of the lower and higher forms of plant life, when it is soon ascertained that he has at his command the knowledge which permits him to comprehend more or less of the history, origin, development and growth of the entire vegetable kingdom. Thereafter, special modifications presented on the part of peculiar forms of plant-life are easily understood with scarcely any additional labor. Types of the various groups of the *invertebrata* should be examined and compared in a like method, all the way from an *amœba* up to a good typical beetle.

Passing next to the vertebrates, good representatives of all the main groups should be examined in the same way; the various structures thoroughly intercompared; studied by means of diagrams; and accounts of their anatomy reviewed in the best text-books on the subject. Useful types for this purpose are seen in the well-known lancelet; in a typical shark or ray; any teleosteon fish; the frog; a turtle; any ordinary bird form, as the common fowl; and, finally, some type mammal, which may be met by either the common cat or the rabbit. This is the plan adopted by the best biological laboratories both in this country and abroad, and of its aims a prominent instructor has said: "The purpose of this course is not to make skilled dissectors, but to give every student a clear and definite conception, by means of sense-images, of the characteristic structure of each of the leading modifications of the animal kingdom; and that is perfectly possible, by going no farther than the length of the list of forms which I have enumerated. If a man knows the structure of the animals I have mentioned he has a clear and exact, however limited, apprehension of the essential features of the organization of all those great divisions of the animal and vegetable kingdoms to

which the forms I have mentioned severally belong. And it then becomes possible for him to read with profit; because every time he meets with the name of a structure he has a definite image in his mind of what the name means in the particular creature he is reading about, and, therefore, the reading is not mere reading. It is not mere repetition of words; but every term employed in the description, we will say, of a horse, or of an elephant, will call up the image of the things he had seen in the rabbit, and he is able to form a distinct conception of that which he has not seen, as a modification of that which he has seen." (Huxley.)

So far as I have examined the course in elementary biology as given here in our public schools, it seems to me to be a worse than useless one, inasmuch as it, by the use of a text-book alone, puts into the heads of the juvenile scholars some very erroneous ideas upon but one branch of biology, that is, physiology. The sole aim would seem to be to impress upon the minds of the pupils that the principal value of the study of physiology is to warn them against the evil results of the use of tobacco and alcoholic stimulants. There is no reason to believe to the contrary but what such misguided, fanatical reformers would also introduce into the public schools some elementary text-book in anatomy, having as its chief aim to paint some lurid picture of the violence done certain structures in the matter of hanging and the pain attached to that operation, in order to warn them against the penalties that might follow willful murder.

Such pernicious instruction as this should be superseded at as early a day as possible by a thorough, sound and practical course in elementary biology, adapted to school children, to the ages from eight to fifteen; and it is truly remarkable the interest children exhibit in such matters when interestingly and rationally taught them. Between the ages just mentioned there is no reason why they should not gain some idea of the distribution of the animals and plants of their own country, at least, taken in connection with their elementary lessons in physical geography. By the use of a good text-book, by colored diagrams, by models and certain material that can be obtained at any butcher's stall, they can easily be taught the structure and physiology of the principal organs, tissues and parts of the human body; and, finally, there may with great advantage be employed elementary instruction in botany by dissections upon specimens of properly selected plants. Farther than this it is not de-

sirable to go. After fifteen years of age our youth can readily grasp the advantages that are sure to flow from a laboratory course, as I explained it a few moments ago. Under a good instructor they can be easily taught in a few lessons all the essentials of dissecting, and the use of a school microscope and the other necessary instruments to commence their work; and it is truly a pleasure to find how often we meet with children at this age who thoroughly enjoy and appreciate such a course of training.

Of course it will not be necessary here to say anything in reference to the value of the study of biology to the students of the subject *per se;* or in other words to those of either sex who have it in mind to follow the science as a calling in life. To them it will be their career, their profession, and that simply demands a thorough academic course, or one in a university, and, later, or partly taken in connection therewith, a general course in biology taught upon the most modern and improved plan. Subsequently the energies of the student will be bent along the lines of the special department of the science which he is best fitted in all ways to pursue. In these days, so broad is the field, that no one ever dreams of doing more than devoting his attention to some very limited part of biology, and indeed, of necessity all of our best biologists are specialists. So narrow are some of the paths, that men are content to confine themselves to even the study of restricted groups of some one class of the main divisions. For instance, the years of the life of some biologist may have been entirely devoted to avian oölogy; another solely to the coleoptera among insects; or in another case to the physiology of plants, and so on.

Speaking for our own country alone, it is very gratifying to note the constantly increasing value placed by the medical profession at large upon biological knowledge; and how the best medical schools in the land insist upon a thorough course in biology as a most important part of their curriculum. And there is every reason to see why this should be so, for it is impossible to comprehend fully the structure of the human body without a knowledge of the morphology of other animals, any more than we can gain the full meaning of human physiology without similar researches into the physiology of all other organized types of the other divisions of the animal kingdom. The morphology, physiology and nature of plants are also quite essential to the trained practitioner of physic; as is psychology, and as complete a knowledge as possible of

the diseases, the origin and history of all morbid growths, and the repair of injuries among all kinds of animals whatsoever. Human reproduction and development is another subject that would be doomed to wear a very one-sided aspect unless the study was rendered clear through the aid of comparisons carried into the other groups of the vertebrata. Many of the *invertebrata* and their several modes of development have also their value, especially certain parasitical forms and the like. Finally, the entire study of all those microscopical species grouped under the various genera of bacteria and their allies, forms a very important part of a medical course, and in reality falls within the science of biology.

In closing, we may truthfully say, then, that as important as a sound knowledge of his science is to the professional biologist; as absolutely indispensable as is a practical comprehension of the subject to the properly educated medical man; it is none the less so as forming a part of the training and education of any person, whatsoever, in the present day and generation, or of him who makes any pretension to having received in his schooling that kind of instruction which fits him for the real battle of life and a clear understanding of a great many of the problems that he will be called upon to face in this Nineteenth-Century-day life of ours.

IV.

Its Growth and Future Influence.

It would hardly seem at all within the range of probability that at any time in the future there will ever be added another to the main divisions of biology, as I have already given them to you; or, in other words, the scope of human knowledge of this kind is now so wide in so far as the consideration of living matter on the globe is concerned that the division of the science into morphology, distribution, physiology, and ætiology will stand for all time as capable of receiving, as a natural classificatory scheme, anything that her students of the future will reveal, or are likely to bring to light. No doubt, as the science becomes more specialized, more or fewer subdivisions will of necessity be differentiated and recognized within the departments in chief, and it will be along these subdivisional lines that the growth of biology will take place, and its extension be appreciated. Even at this very hour, the scalpel and the microscope are ever busy in the hands of science, investigating the structure of every kind of existing animal and all varieties of plants in many parts of the world. These researches will go steadily on and that, too, in greater and greater number, in an ever widening field, and with an ever increasing interest and ardor.

As we are all aware, morphology constitutes one of the most important divisions of biology, and it is plain that there can be but one limit to its work, and that is when we are in possession of a full and correct account of the struture of every species of animal or organism now existing in the world's fauna, as well as an equally full knowledge of the structure of the entire vegetable world from the very lowest forms of plant life to the most high and complex ones. Not only that, but such a far-reaching knowledge should be made comparative in every sense of the word, and include a complete comprehension of every kind of structural anomaly. Moreover, those

investigations will be so extended as to include, apart from the question of distribution, exhaustive accounts of the comparative morphology of all the fossil remains of animals and plants that the explorations of the palæontologist of the future will have been so fortunate as to have discovered. At the present rate of progress, which in its way is quite marvelous, this will, nevertheless, entail the labors of the hands and minds of biologists for generations and ages to come. For, in these days, you must understand, we can hardly be said to have mastered more than an average comparative knowledge of the leading types of the world's flora and fauna. Much that we pretend to know nowadays is gotten at by the reliance we place in the general uniformity of plan and structure throughout all Nature, animated and otherwise. This, for the present, carries us very safely for a long ways, yet every scientist fully appreciates the fact, that our knowledge can only be real when the yet unexamined structures have all been exhaustively investigated. In connection with this, too, it must be remembered that a great many plants still exist in as yet unexplored parts of the world which have not, for that reason, come into the hands of science at all.

What I have just said of morphology applies with equal truth to physiology, and what is now much of an *a priori* nature in our knowledge in this science will become in the far distant future real and actual through exhaustive observations upon the functions of every possible tissue and organ throughout the entire range of animal and plant life as now existing in the world. It is believed that such a full and comparative knowledge of function will, during ages to come, grow and develop *pari passu* with the growth of our knowledge of structure, and the two continually flash light adown each other's paths of advancement.

There is no structure throughout all animated Nature that has received anything like the amount of anatomical examination and research as has the body of man. For centuries it has been the subject, the species above all others, that has engaged the close attention of the morphologist, physician and student. Both sexes and the young of all stages have come in equally for their share of it; while man's development has been passed thousands of times in review by investigators stamped with every shade of ability. Notwithstanding all this there still remains not a little, both in the anatomy and physiology of man, which is still within the grasp of the un-

known. Several of the structures and organs of our bodies are still enigmas to us in so far as we have been enabled to appreciate their morphological significance. The same strictures apply to the functions or to the physiology of those organs. Much in the developmental and homological history of man's skeleton is still obscure, and especially is this true of the skull. Even in apparently so simple a system as the muscular, or in the case of the ligaments, we still are presented with problems that up to the present time have remained unsolved. Still greater difficulties have been met in the case of some of the structures of the brain and general nervous system; in the suprarenal capsules, the thyroid and thymus glands; the spleen; special structures of the eye, ear and tongue; and, indeed, the list when taken as a whole, is, as I have just said, not a short one.

Now if this be the case with man, it is not difficult to imagine how vast must yet be the store of facts still unrevealed in the entire range of the morphology of all other animals and plants apart from him. As I have stated several times we are in possession of the main fundamental plan of structure that characterizes animals in Nature to be sure, yet how ignorant we still are of the well-nigh limitless array of the details of structure. And it is the discovery of the presence and meaning of these special structural details in certain forms which will explain not only the morphological significance of the obscure points in man's anatomy, but the corresponding ones in all those other animals wherein the new structure is found to exist.

Permit me to present you with one or two examples exhibiting the manner in which the discovery of new structures in the lower animals not only throws light upon the corresponding structures in allied forms, but also often upon the most obscure points in the anatomy of man. Now there is a small, glandular structure at the base of the brain in all men, and in all mammals, so far as I can recollect, which bears the name of the pineal gland. Until within a very recent time the uses of this structure were entirely unknown, and not a work upon either human anatomy or physiology threw any light upon the subject. Descartes supposed it to be the seat of the soul! But the nineteenth century biologist knows better than that, at least; for, thanks to the researches of Baldwin Spencer, of England, made in 1886, we have, I think, a better solution of the case. Mr. Spencer, in making dissections upon that unique form of lizard from

New Zealand, known to the zoölogist as *Hatteria*, discovered that it possessed on the vertex of its skull, in the mid-parietal region, a small perforation or foramen, and in the brain beneath it, in the median plane, the more than evident rudiments of an eye—a third, mid-brain eye. This structure was connected with the brain below by its nervous stalk, the proximal extremity of which, or its root, corresponding to the origin of the glandular structure just spoken of as the pineal gland, which occurs in so many other animals. Morphologists immediately examined a great variety of other lizards in various parts of the world, and many were found to possess it in different states of perfectness. Tracing it through the animal series, it soon became evident that in its nearly completelv rudimentary condition in man and the higher mammalia it is now but represented in them by the pineal gland, or the basal, vestigal end of the nervous root-stalk.

Another very interesting example of this sort is the discovery, a few years ago, by my talented friend, Dr. J. Bland Sutton, the British anatomist, of the morphological import of the round ligament of the hipjoint. This structure has long been an anatomical puzzle, and is technically known to anatomists as the *ligamentum teres*. In man it is a round ligamentous cord passing from a shallow pit on the head of the thighbone to the base of the articulatory socket for that bone situated at the side of the pelvis. All sorts of opinions have been held concerning its nature, but the researches of Dr. Sutton have, it would appear, settled the question; and he has quite conclusively shown that the *ligamentum teres* must, originally have formed a part of the pectineus muscle, one of the muscles of the upper part of the thigh and hip. The ligament is very generally found in the mammalia, though that class offers a number of remarkable exceptions. So far as at present known but one bird lacks it, and that is the cassowary (*Casuarius appendiculata*), while in reptiles it has thus far been found to be universally present, being represented by a ligamentous band.

"It is in the horse that we first get the glimpse of the true nature of the ligament, for in this animal it consists of two parts, one hidden within the joint termed the cotyloid portion, the other passes out of the cavity to join the *linea alba* at its junction with the pubes, hence it is termed the pubio-femoral portion. From this band the pectineus takes origin. * * * * *

"In the ostrich the *ligamentum teres* has a true tendinous

structure. It is dense and strong, contains a large quantity of yellow elastic tissue arranged in *fasciculi*, as in the tendon of a muscle." (Sutton.)

Now the ambiens is another remarkable muscle of the thigh in birds which has very much excited the interest of morphologists, and in the adult ostrich it is seen to be connected by fibrous tissue with our *ligamentum teres*. In the chick of the ostrich this fibrous tissue is seen to be a muscular slip, and Sutton believes, on the best of evidence, that that muscular slip and the ambiens represent the mammalian pectineus muscle. He is then enabled to trace its varying relations and conditions from the lizard *Sphenodon* to man, proving most conclusively its true nature as I have just given it. The account, or rather chapter, is concluded by his saying:

"There is no ligament in the body which can boast such an extensive literature, or has exercised more the ingenuity of physiologists and surgeons than the one we have been considering." * * * *

"Teleologists like Paley have been enraptured with this structure, and anatomists have ascribed to it wonderful mechanical resistance and uses. Alas! in this, as in so many like cases, morphology demands for it a low level, and determines it to be a vestigial and practically useless ligament. In this sense teleology is as poetry, but morphology as plain history."

These two very excellent illustrative examples will serve to show the direction of the lines along which morphology of the future must of necessity progress; and the advance of the science of physiology will be quite in keeping with it. And, it may be said, inasmuch as the first stands for all those phenomena of living organisms which relate to form, and the latter for all those which relate to action, that however independently these two lines of inquiry may be progressing now, the day must assuredly arrive when biologists will appreciate that, perhaps, after all, but one outcome is common to the two, and it is indicated by the same molecular processes. Foster has recently said:

"The problems of physiology may in a broad sense be spoken of as threefold. (1) On the one hand, we have to search the laws according to which the complex, unstable food is transmuted into the still more complex and still more unstable living flesh, and the laws according to which this living substance breaks down into simple, stable waste products, void or nearly void of energy. (2) On the other hand, we have to determine the laws ac-

cording to which the vibrations of the nervous substance originate from extrinsic and intrinsic causes, the laws according to which these vibrations pass to and fro in the body, acting and reacting upon each other, and the laws according to which they finally break up and are lost, either in those larger swings of muscular contraction whereby the movements of the body are effected, or in some other way. (3) And, lastly, we have to attack the abstruser problems of how these neural vibrations, often mysteriously attended with changes of consciousness, as well as the less subtle vibrations of the contracting muscles, are wrought out of the explosive chemical decompositions of the nervous and muscular substances; that is, of how energy of chemical action is transmuted into and serves as the supply of that vital energy which appears as movement, feeling, and thought."

These being the lines along which physiology must progress, my inclinations strongly prompt me to next point out to you what will probably be some of the advances made in the future, in "physiological psychology," psychology pure and simple, and in psychics; for I am especially interested in such fields, and my connections with the British Society for Psychical Research have, through the admirable "Prcceedings" they publish, given me unusual opportunity to keep pace with the science; but neither our space nor our time will admit of much in this direction. The society I have just mentioned has, enrolled among its long list of corresponding, active, and associate members, many distinguished men and women of many nationalities, and all are heartily interested in the progress of every department of psychology. We need no better proof, as a guarantee of its sincerity of purpose and aims, than to see the names of Lord Tennyson, the Right Hon. W. E. Gladstone, the bishops of Carlisle and of Ripon, John Ruskin, and a host of other weighty names—as we do—upon its list of members. Among the best workers of the society there is a strong tendency to treat psychology by precisely similar methods whereby we deal with any of the natural sciences. Assuming such things as thoughts and feelings to exist it is contended that they present themselves as vehicles of knowledge, and it becomes one of the most important tasks of the psychologist to ascertain by strictly scientific experimental methods the correlations existing between those various sorts of thoughts and feelings on the one hand, with the definite conditions of the brain on the ther. Bey ond such premises psychology passes into

metaphysics, but the science has centuries of work before it in the fields I have just indicated. An enormous amount of evidence of all kinds, and often of the most peculiar kinds, has been submitted to the society for its consideration, and the great mass of this has been critically dealt with after the most careful scientific methods. Mr. Frederic W. H. Myers, one of the two honorary secretaries of the society, has recently said, in referring to the work accomplished by its efforts:

"There has been what we regard as adequate evidence of telepathy—a power of direct communication from mind to mind--which is difficult to reconcile with the ordinary materialistic synthesis. There has been evidence also—less in quantity, but to me convincing—of clairvoyance, of the supernormal acquisition of knowledge as to present, past, and perhaps even future things. And there has been evidence which points *prima facie* to the agency of departed personalities, although this evidence has also been interpreted in other ways."

These convictions of Mr. Myers are not held by all the members, though for one other I can say the evidence that has been submitted and examined has quite satisfied me of the truth of telepathy. Further than that, I have nothing to say at present, though I would add it must be fully evident to anyone that the results aimed at, were they attained and proven, are of greater importance to all mankind than the sum total of all else that can ever be accomplished by every other science known to us united.

Finally, the society has added very materially to our knowledge of hypnotism, hallucinations, dreams, premonitions, and a number of other allied subjects, and progress in several of these directions is very satisfactory and material.

From the consideration of such supreme matters as are offered us by the science of physchology, we pass again to take to note of the growth and advancement of another department of biology which has a world-wide interest for all lovers of Nature, and all that is lovable in Nature. I refer to that science which to both the popular mind and to the naturalist has for ages been known as zoölogy—the natural history of animals, pure and simple. Taken as a whole the world over, progress in these fields of recent years has been, it seems to me, rather in the direction of amassing material for museums and private collections than of making carefully recorded and exhaustive accounts of the life-histories of animals. As

highly important as it is in its way, the mere accumulation of specimens of either animals or plants, and bestowing upon them appropriate technical names, and defining the position of such species in the natural system is by no means the end and all there is to zoölogical science. No one, I think, can better appreciate the great value of the kind of material of which I speak, than I do. Take mammals, for example, there can be no question about the desirability of collecting both alcoholic specimens, skins, and skeletons of all the mammals possible, in an country; of naming them, describing them and classifying them, as far as the material will admit. Yet, sometimes, it is very discouraging to go into our large museums, and, upon examining those specimens, to find really how very little we know of the life-histories, the intimate habits, or even the geographical distribution of the specimens that have been so carefully collected. In this country we are, even to-day, wonderfully ignorant of many of the habits of some of our commonest and most abundant mammals, and, especially, the smaller varieties of them, though what I have said is equally applicable to many of the larger forms.

In the majority of instances in the case of the latter this is very unfortunate, as all over the world many of them are rapidly becoming extinct, and some, indeed, have become quite so, even within very recent times. Not only is it very essential that we should possess as complete accounts as possible of the entire morphology of all the forms to which I have reference, but upon all occasions, wherever and whenever opportunity offers, both in Nature and in the zoölogical gardens, we should make most careful observations upon every trait any particular animal exhibits. And, above all else, such studies should be made comparative and the comparisons based upon true scientific methods. It is desirable to know as accurately as possible the exact geographical range and distribution of each species; its relative abundance; its rate of increase or decrease, as the case may present; its enemies and the animals which it itself in turn attacks; the diseases and parasites to which it is subject; its food at various seasons of the years, and its choice of one food when deprived by any cause of another; its habits as affected by the seasons, by the elements and by vicissitudes of climate; its peculiar habits; its habits in confinement and its diurnal and nocturnal habits; its changes of pelage; all that refers to its reproduction, development, relations of the sexes and their behavior when associated;

the way in which they rear their young, and everything that pertains thereto; and, finally, statistics as to what economical value it may possess, and other matters. So it will be seen that, in the case of any species of mammal, to give a complete account of its life-history in a thoroughly scientific manner is far from being a light task. But this is by no means all I would exact of the zoölogist, for such historical accounts, to be of the greatest value, should be made comparative in every sense of the word. Habits and all the other matters I have just enumerated, having been collected for the most lowly organized types of the mammals of any particular family or group, should be properly compared with the corresponding traits as found in the animals next above them in the same group. Then the digested data, the outcome of such studies when systemized, should, in turn, be compared with the similar and comparable knowledge derived from like observations upon the next most nearly affined group or family of mammals, and that, too, the next higher in the scale of organization.

Thus it should be carried on and upward through the system, from the most lowly organized types to include the various genera of new and old world apes and their near kin. As we ascend step by step we should be particularly careful to note any new habit that may arise, especially those habits which appear to indicate any advance in the mental faculties, or kindred attributes. With such knowledge at our command, and systematically formulated for proper use we are in a position to undertake identically the same kind of studies in the case of all the various types and races of men, or the world's anthropofaunæ, beginning with the very lowest types of man known to us and ascending the scale to those most highly organized in all particulars—physically, mentally, morally and intellectually. It is very desirable that this should be done, done well, and made thoroughly comparative. A great deal has been done already along such lines, but in my estimation very little in comparison with what is actually required. By such studies much light may be thrown upon the question of the origin of the mental powers in man; the tracing of the origin of language, and of the special development of the intellect; of the origin and development of the moral qualities; of certain desires and passions; of the relations of the sexes; origin of marriage; and, finally, a great deal else which may be said to be the natural outcome of the development of all that is included in the social instincts

of man. Carrying these studies a little further along and we lay down the true principles which constitute the foundations of the science of sociology, which, in truth, is nothing more than the science of social phenomena as exhibited in human society; and its growth clearly shows it to belong to the group of biological sciences.

As already intimated, we may, in the future, and that, too, for many ages to come, look forward to an ever-increasing knowledge of the science of distribution—the distribution of animals and plants both in space and in time. Whatever may be the amount, however, of this knowledge yet to be possessed, we can hardly look for anything more than an amplification, by an accumulation of an enormous array of additional facts, of the scheme and of the laws of distribution as they are now known to us. Progress in this science, in the future will consist in a refinement in detail of what we already know about the distribution of the world's existing floræ and faunæ. Many new species of organisms will come to light, but as they do we will sooner or later come to be familiar with their exact geographical ranges. Among the minuter forms of life this will, of course, requires much research, extending over many ages of time; and in the case of the vast majority of the smaller types of marine life it will require a considerably longer time before we will possess any exact knowledge on the subject, more especially in the case of the deep-sea forms. Indeed we may add here that there probably yet remain unknown to us myraids of interesting animals, of all kinds, in the ocean's depths, but even these the labors of our marine zoölogists are slowly bringing to light. As to the distribution of plants and animals in time, pretty much the same kind of progress is indicated. Our palæozoölogists and our palæobotanists in the future, no doubt will have their explorations rewarded by the discovery, ever and anon, of many specimens of fossil plants and animals long since extinct. These discoveries will in their turn react by shedding an ever-increasing light upon the question of the distribution of animal and plant life as we now find it in the world, and thus solve many problems which are, as yet, quite obscure. Notwithstanding this view of the case, we may look at any time for interesting developments all along the line; such as, for example, the discovery of vertebrate life in the Cambriam, a most important discovery re-

cently made by Mr. Walcott of the United States Geographical Survey.

Knowing as we do the fundamental morphological plan of structure as it is variously exemplified among the several orders of plants; the main groups of the invertebrata; and among the vertebrates; we can look for nothing more among all the palæonlotogical material which will assuredly be brought to light in the future than interesting modifications of those several plans of structure. Such discoveries in some instances, undoubtedly, will bring before us some very remarkable facts, but they will ever be in harmony with the facts already known to us. The most we can look for in such directions is a progressive refinement in our knowledge of the affinities of existing organisms, and the affinities of the various species, genera, and families long since extinct. Light will constantly also be thrown upon the morphological enigmas as they now stand to us among many of the existing species of animals and plants.

The fact I wish to distinctly impress however, is that our knowledge of morphology, in general, is at present of such a nature that it absolutely admits of our prophesying, from the known data of the anatomical character of animals or plants in our possession, what kind of forms we will probably meet with among the yet undiscovered fossil types in the future. Such prophecies have in several instances actually been made, and it is one of the grandest triumphs of which humanity has to boast, that in a number of cases those prophecies have actually been fulfilled. For instance, the fundamental plan of the hand and foot among all the higher types of vertebrates is pentadactyle, or five digits upon either member. Now when we discovered the fossil *Orohippus* in the line of the ancestors of our modern horse, it was seen that it had but four complete toes on the front limb and three toes upon the hind limb. The prophesy was made, based upon our knowledge of the fundamental plan of the foot and hand in the group to which it belonged, that if we were ever so fortunate as to meet with the ancestral form from which *Orohippus* was derived it would approach still nearer the pentadactyle type. A number of years afterward the prophecy was most beautifully fulfilled by the discovery of the fossil *Eohippus*, in the ancestral line of the horses, which supplied the required conditions.

Permit me to present you with one more instance of this kind—not the first one that has happened, nor, mark my word, will it be the last one of a similar nature: The

lesson it teaches those who may be more or less uninformed in such matters—and everyone here present being on the right side of the line, may smile at the class to whom I refer—is invaluable. It will well exemplify the certitude of the predictions of biologists in such premises, equipped as they are with their present-day acquired morphological facts, as it likewise proclaims that it is not even necessary to have in our possession the entire skeleton of the fossil remains of the animal discovered to safely predict as to its position in the natural system. A split slab of stone, of considerable geological age, from the quarries of Montmartre is presented to the distinguished French *savant* Cuvier. Its two halves contain the greater part of the skeleton of a small mammal, but only a few of the teeth of the lower jaw happen to be exposed, and these Cuvier carefully examines. The exposed material you will at once appreciate is but fragmentary, yet that sagacious French biologist made no hesitation in pronouncing the animal an opossum, guided as he was by the evidence in sight, and duly assigned the fossil to that genus. Opossums are unlike most of the mammalia, inasmuch as they possess two small bones, articulated mesially to the fore part of the pelvis, which have been called the "marsupial bones," but the function of which has not been definitely determined. Now, although the animal Cuvier had in hand had been dead and fossilized and encased in rock for untold ages, he prophesied that when they came to clear away the matrix which contained it there would be discovered, in front of the pelvis, the two usual bones that characterize that part of the skeleton in the opossums, and this prediction he made from an examination, you will remember, of only a few of the teeth. Other naturalists were invited to witness the disinterment, so confident was Cuvier of his prediction, and, be it said to the credit of biological science, he was most eminently correct in his ideas, for the marsupial bones of the fossil were duly exposed *in situ*. Now the application of such a philosophy as this not only holds true of mammals, but it holds true of all animals and plants whatsoever, that have ever existed since the beginning of the world. Not only this, but with the increase and the better knowledge of such material, our prophecies can be made with an ever increasing certainty of their correctness, so that, in time, without ever having seen certain fossil animals at all, it will become possible for the skilled palæontologist to very closely designate the various kinds that must have of necessity existed;

that is, must have existed in order to complete the genealogical tree of all animal and plant forms, applying, as I do, the same statement to botany. Or, as Huxley puts it:

"The same method of reasoning which enables us, when furnished with a fragment of an extinct animal, to prophesy the character which the whole organism exhibited, will, sooner or later, enable us, when we know a few of the later terms of a genealogical series, to predict the nature of the earlier terms." Professor Cope, our distinguished American palæontologist, upon one instance, at least, has already verified what I have just quoted from Huxley; for long before its discovery he prophesied what the main osteological characters of one of the ancestors of a certain group of fossil animals essentially must have been, and that such and such an animal certainly must have existed. Years later not only was the fossil found, but it was characterized by possessing a skeleton such as Cope predicted it would possess, and that skeleton is now in the hands of science

Taken collectively the progress of that department of biology which we now have under consideration will be represented then, in the future, by the progress made along the lines developed by the palæontologist; the student of the distribution of animal and plant forms in time; and lastly, the zoögeographer, or him who deals with the science of the distribution of all forms of life in space.

The combined results of the laborers in these fields will be an elaboration of our knowledge of the true affinities existing among all animals, both in time and in space, as well as the true affinities existing among all plants, from their beginning in time up to include all modern floræ. The trunks, the main branches, the principal limbs, and even many of the twiglets of these two mighty genealogical trees are now well known to us, so well known, indeed, that it is hard for me to conceive of any discoveries that may be made by the palæontologist in the ages to come that could excite in the philosophic biologist anything that could at all be likened to puzzled wonderment. The unfinished offshoots of the genealogical tree of descent await the engraftment upon them of the yet undiscovered fossil forms concealed within the solid crust of the earth; and however extravagant the modifications of many of those forms may prove to be, we are well assured that they can only be modifications in any case of the at-present-known types of structure now existing in nature;

and so, however intense the interest they may excite, they can create no such thing as revolutionary surprises. They will have, however, beyond all doubt, the effect of constantly making clearer and clearer our conceptions of the material scheme of the universe; the operations of natural laws; and the interrelationship and interdependence of all living things since life first appeared upon earth. It is this kind of progress which is taking place at the present hour, and will continue just so long as the mind of man pleases to carry his inquiries and his researches into such fields; and there appears to be no evidence at this time of his relinquishing them.

As has already been pointed out, the known phenomena of biology comprised by the several sciences of morphology, physiology and distribution are constantly leading us up, face to face, to that question of all questions, the origination of living matter upon this planet, and the causes which have led to it. Such knowledge as we possess and in any way sheds any light upon this subject, is referred to—as I have already said—in that fourth department of biology designated, as you know, as ætiology; and it, in its present stage of development, must be considered quite in its infancy. Especially must this be regarded as the case, inasmuch as many of our most competent living biologists are of the opinion, an opinion shared by myself, that we are as yet in absolute ignorance of the causes which have led to the origination of living matter. From the very nature of the case palæontology will never be enabled to furnish us with the direct evidence of the character of the primoidal forms of living organisms, much less the proof as to how those forms were first endowed with life. Still, evidence of another kind, and most conclusive evidence, leaves no doubt in our minds as to what the character of those primoidal forms must have been, though that evidence leaves us still utterly in the dark as to how life arose in them. So far as our present-day knowledge carries us, everything seems to point to the conclusion entertained by most scientists that all planets and stars, alike, now composing the universe, are either at present in a gaseous state or have at some time or other passed through such a stage. Further, we have every reason to believe that this planet has likewise passed through a similar stage, and that being the case its condition at that time must have been such that no living matter could have possibly existed upon it. From this we are led to infer that living matter must originally have arisen from non-living

matter, an hypothesis—it may be said in passing—quite in harmony with the doctrine of evolution. Science, as yet, is not in possession of any direct evidence which could be considered demonstrative of the fact that any such a phenomenon has ever taken place in Nature at any time within the period of the recorded existence of life upon the earth. You will remember that I said such a theory is spoken of as the theory of abiogenesis, and although we have no trustworthy proof of its actual occurrence, "it need hardly be pointed out," as Huxley says, that that "fact does not in the slightest degree interfere with any conclusion that may be arrived at deductively from other considerations that, at some other time or other, abiogenesis must have taken place." From these premises we are compelled to believe that the progress for ætiology in the future must be the accumulation of evidence in support of those other considerations to which allusion has just been made, and that such evidence will in time be forthcoming I make no manner of doubt, any more than I entertain any doubt in my mind that the deduction which can be made from it will be so weighty that it will place the question of abiogenesis upon as secure a foundation, in so far as its occurrence is concerned, as that of any other inductive hypothesis which has been accepted as good as proven by all thinking people who ever pay any attention to such matters.

My remarks upon this subject would not be complete did I not at least make brief allusion to the provisional hypothesis, advanced by Darwin, which he termed "pangenesis," whereby he attempted to explain the phenomena of reproduction in organisms. In one of his works he says:

"I venture to advance the hypothesis of pangenesis, which implies that every separate part of the whole organization reproduces itself. So that ovules, spermatozoa, and pollen-grains—the fertilized egg or seed, as well as buds—include and consist of a multitude of germs thrown off from each separate part or unit."

For some reason or other this hypothesis does not seem to have excited any lasting interest, either in the lay or scientific mind, although we cannot claim that as any valid proof militating against its truth, and that is a matter which time and amplification of our knowledge in the premises alone can settle.

Even the biogenetic view of the origination of life has its enigmas for us to solve, and so far as the initial ques-

tion of impregnation, for example, is concerned even the lucid description given us of it in the common fowl by the late distinguished British embryologist, Mr. Balfour, may not satisfy the minds of all of us as to exactly how life actually begins. Mr. Balfour says that impregnation, in the case of the chicken, "occurs in the upper portion of the oviduct; the spermatozoa being found actively moving in the fluid which is there contained." * * *

"We have as yet, as far as the fowl is concerned, no direct observations concerning the changes preceding and following upon impregnation; nor, indeed, concerning the actual nature of the act of impregnation." * * * * *

"In other types, however, these processes have been followed with considerable care, and the result has been to show that prior to impregnation a division of the ovum takes place into two very unequal parts. The smaller of these parts is known as the polar body, and plays no further part in the development. In the course of the division of the ovum into these two parts the germinal vesicle also divides, and one part of it enters the polar body while a portion remains in the larger segment, which continues to be called the ovum, and is there known as the female pronucleus. Impregnation has been found to consist essentially in the entrance of a single spermatozoon into the ovum, followed by the fusion of the two. The spermatozoon itself is to be regarded as a cell, the head of which corresponds to the nucleus. When the spermatozoon enters the ovum the substance forming its tail becomes mingled with the protoplasm of the latter, but the head enlarges and constitutes a distinct body called the male pronucleus, which travels toward and finally fuses with the female pronucleus to constitute the nucleus of the impregnated ovum."

From this point it has not proved especially difficult for the trained embryologist to trace the development of the chick of the fowl to that stage of development when it quits the eggshell that incases it during the early stages of its existence. And it may be said that the statements we have quoted from Mr. Balfour may carry with them considerable comfort to him who entertains the biogenetic view of the origination of living matter, still it seems to us that even a little more light in this direction would not come altogether amiss. One, for instance, almost feels inclined to ask, what is the nature of the life as exhibited on the part of the spermatozoon? I have examined the live spermatozoon of the highest types of vertebrates known to us, and am familiar with the

physiology of the *Protamœba* and the tadpole, and am free to confess that I would be glad to have it made clear to me that the living principle, the very essence of life is identical in all three of these organisms. Still more would I be glad to know the precise difference 'twixt a live amœba and a dead one; 'twixt a live spermatozoon and a dead one; and, finally, is the unimpregnated ovum of the female endowed with life, or is life simply brought to it by the male spermatozoon? Surely the young science of ætiology has many questions to answer for us.

Finally, we have the words of Huxley upon this subject, in his able address on "spontaneous generation," delivered before the British Association for the Advancement of Science, at the Liverpool meeting, in September, 1870; and although that is nearly a quarter of a century ago, it yet remains a very clear exposition of the case, and he then said: "Though I cannot express this conviction of mine too strongly, I must carefully guard myself against the supposition that I intend to suggest that no such thing as abiogenesis ever has taken place in the past or ever will take place in the future. With organic chemistry, molecular physics and physiology yet in their infancy and every day making prodigious strides—I think it would be the height of presumption for any man to say that the conditions under which matter assumes the properties we call 'vital' may not some day, be artificially brought together. All I feel justified in affirming is, that I see no reason for believing that the feat has been performed yet. * * * And, looking back through the prodigious vista of the past, I find no record of the commencement of life, and, therefore, I am devoid of any means of forming a definite conclusion as to the conditions of its appearance. Belief, in the scientific sense of the word, is a serious matter and needs strong foundations. To say, therefore, in the admitted absence of evidence, that I have any belief as to the mode in which the existing forms of life have originated would be using words in a wrong sense. But expectation is permissible where belief is not; and, if it were given me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions which it can no more see again than a man can recall his infancy, I should expect to be a witness of the evolution of living protoplasm from not living matter. I should expect to see it appear under forms of great simplicity, endowed, like existing fungi, with the power of deter-

mining the formation of new protoplasm from such matters as ammonium carbonates, oxalates and tartrates, alkaline and earthy phosphates, and water, without the aid of light. That is the expectation to which analogical reasoning leads me; but I beg you once more to recollect that I have no right to call my opinion anything but an act of philosophical faith." * * * *

"So much for the history of the progress of Redi's great doctrine of biogenesis, which appears to me, with the limitations I have expressed, to be victorious along the whole line at the present day."

As I have said, these convictions of Professor Huxley's were expressed by him nearly a quarter of a century ago, and in the interim between the time of their expression and the present hour the keenest methods of experimentation in such fields have been steadily kept up in many laboratories, by the most competent observers, and the result has been that an ever-increasing belief in the idea that abiogenesis can take place; that is, in certain low and simple organisms we may have living matter arise from non-living matter, and it was what took place at the dawn of life upon earth. This is my belief, my conviction; and its complete demonstration when accomplished will be far from a matter of surprise to me. During the last century we have wrested so many of Nature's secrets from her that I feel that the earnest truth-seekers in biology will by their persistent efforts in such directions compel her to surrender this one likewise, perhaps the most or one of the most important ones she still withholds from humanity.

Biological advance, in all its departments, for the last half century, has, as we are all well aware, most powerfully influenced the entire trend of human thought, and wherever its modern doctrines have come in contact with modern society, capable, in whole or in part of logical reasoning, they have had the effects of completely revolutionizing many of its time-honored ideas, and much of its time-honored philosophy. To those who have kept pace with scientific advance during rather more than the latter half of the time of which I speak, it is unnecessary to recall the fact that that revolution came upon the world of thought in no very gentle manner, for the roar of its trained artillery and the rattle of its musketry of millions of facts thoroughly aroused every mind in the entire army of the world's thinkers. And controversies of the most seething nature characterized the war that followed, and may hardly yet be said to have terminated,

though where facts constitute the ammunition used the contest cannot be long prolonged.

Your lecturer claims not to be quite as sanguine as many another teacher in biology with whom he ha acquaintance, but he has that faith in the rate at which human thought is now moving to be fully of the opinion that we have not very far to look into the future to be enabled to see the time when the fundamental principles and common facts of biology shall be taught, and properly taught, in every school of whatever size or scope, in the country. It will then be thought quite as essential for our growing youth to be familiar with the general features of the anatomy and physiology of their own bodies as it will be to be able to give the leading incidents of the war of 1812; and, perhaps, be considered equally as practical. Moreover, in that time, when it arrives, it will be considered quite as derogatory to the name of a liberal education to have our youth ignorant of the laws of descent as applied to all living organisms; of the laws of distribution; and the names and general habits of the fauna of his own land, as it will and now is to have them ignorant of the main characters of the earth's atmospheric envelop or the law of gravitation. To me there is no better indication of an unbalanced, one-sided education, at the present day, than to find some young man more or less conversant with what his physical geography has to teach him about the Arctic Ocean currents, and, yet, at the same time, laboring under the impression that the biggest creature that habitually swims and lives therein—the whale—is "a great fish;" whereas, any elementary text-book in zoölogy, upon a moment's consultation will set him right, and demonstrate the fact that a whale is no fish at all, but on the other hand is just as much of a mammal as a horse or an elephant, with all the main characteristics of a mammal, even nursing its young at the breast. Yet this is but one case, chosen for illustration, from among hundreds of others.

One of the greatest living expounders of modern science, in speaking of the educational value of biology in general and of physiology in particular, has said:

"Biology needs no apologist when she demands a place —and a prominent place—in any scheme of education worthy of the name. Leave out the physiological sciences from your curriculum and you launch the student into the world undisciplined in that science whose subject-matter would best develop his powers of observation;

ignorant of facts of the deepest importance for his own and others' welfare; blind to the richest sources of beauty in God's creation; and unprovided with that belief in a living law and an order manifesting itself in and through endless change and variety, which might serve to check and moderate that phase of despair through which, if he take an earnest interest in social problems, he will assuredly sooner or later pass." (Huxley.)

But, it may be asked, are we not awakening, indeed, have we not already awakened to the realization of the force and point and truth of all that is contained in the cogent passage we have just quoted? Have we not very good evidence upon all sides, however slowly it may be advancing or however imperfectly, of just such changes being introduced into the workings of our educational machine, into the very texture of all our educational schemes everywhere? There can be no doubt about it, and one must have his eyes shut, in these days, with a very tight squeeze, who fails to see that just such changes are coming about; that the present is most emphatically an age of transition in all such matters, the like of which has never been seen by the world before, since her history first began. No one can doubt for a moment how powerful the influence of such radical changes in our educational methods will prove in the future of the race. Yet, it constitutes nothing more than an evolution of ideas, a growth quite comparable with the evolvement of many other things the world has seen and produced. A passage, as it were, from an age more or less characterized by an intellectual thralldom, to another and higher one, stamped chiefly by an almost universal exercise of common sense, by a universal diffusion and absorption of all kinds of knowledge, and a general desire to arrive at the real truth in all things; to expose Nature's true inwardness, and demonstrate her every law; to observe, compare, and verify every new fact acquired, and apply, as far as possible, the digested knowledge thus obtained to the practical ends of human pursuits.

In short, then, taking the science of biology in its entirety, represented by its enormous army of actual workers upon the one hand and its innumerable host of supporters and believers on the other, one may scrutinize its ranks from the head of the column to the last file closer in the rear, and it will be seen that they advance under but a common standard, and that standard has emblazoned upon its center field but one motto, and its words

are: "We seek the truth and the truth only." Such being the broad field of its operations; such its progress; and such its aims, it can easily be conceived by all who care or have the power to raise themselves in their stirruos and scan the unexplored domain that lies in the way of this column's advance, or those who may be found there in that territory to meet it, what its influence must be in the future, both the most immediate future, and that future which shall close the career of man upon earth.

Truth must and ever will powerfully prevail; and when truth is brought in collision with those human opinions, those human institutions, those human ideas which cannot bear the full blaze of her scrutiny, there can be but one fate for them all—they are completely overcome, and thereafter, in their disarmed state, can but forever stand aside, as beacons of human experience, to pass down into human history as perpetual warnings of the danger to man's progress, that danger which is ever represented by erroneous ideas and by those practices unguided by the knowledge of truth and the knowledge of fact.

Nations and governments do feel now and must feel still more in the future the influence of this advance in natural knowledge, for nations are made up of individuals, and when truth pervades the part it must eventually pervade the whole. But nations have nothing to fear from such quarters, and only benefit can follow, benefit which must come in the light of the knowledge of man's true place in Nature, his relations to the universe at large, and finally, how his life, his happiness, his career, and his material progress is completely under the sway of those natural laws that in common affect both the earth and every living organism upon it. Similarly, all of man's social and educational institutions must be influenced for the better through the same means in the future. Art will receive her impress, for much in art is a reproduction of what we see in Nature, and if it be that the artist cannot read Nature aright his erroneous ideas of her will, of a certainty, make their appearance in his work.

Throughout this course of lectures several opportunities have been taken to point out what a profound influence biological progress must exert upon the profession of medicine in the future, and this must be sufficiently clear, inasmuch as morphology and physiology lie at the very base of that science. A moment's reflection is alone necessary to appreciate how the same influence will con-

tinue to be extended to its closely allied profession of medical jurisprudence, for very frequently an exact knowledge of physiology is demanded of its practitioners to come to just conclusions. And thus it can be shown that there is not a single activity in which men engage that will not, in the future, either by a direct knowledge of one or another of the biological sciences, or through an improvement in our methods adopted for mental training engendered by their introduction into our system of education, be more or less beneficially influenced thereby.

We have another great institution with us that of recent years has been powerfully influenced by the growth of our newly acquired knowledge of natural laws, and must, of necessity, appreciate that fact still more sensibly in the future. I refer to religion and to Christianity; but there has been so very much said and written upon this subject, during the last half century, that it would seem to be almost impossible to even refer to so vast a field for comment here with the hope of bringing any new light to bear. To my mind, time alone is required for the true and lasting adjustments to be arrived at in such premises. The broadest thinkers in the church are not slow in seeing that truth alone controls scientific progress; every page in human history establishes that fact, and surely, religion has nothing to fear from any such quarter. And it must be evident that wise indeed will be that church that can most rapidly and surely accommodate itself, at all times, to the intellectual growth of the world. It can but redound to her credit, broaden her conceptions, and improve religious teachings and methods. Scientific criticism is so keen, so exacting, and so impartial, in these days, that it constitutes the most formidable foe extant to anything that may arise, even within the very ranks of science, at all incompatible with what is true; and it is simply out of the question to have any hypothesis live for a moment, come from whence it may, unless it be reared upon ample, well attested facts and figures. It will meet with almost instant refutation at the very hands of scientific men themselves, and if any layman choose to test the truth of this, and test how exacting science is in these respects as to the question of matter of fact, he has but to do and publish some small piece of monographic work in biology, into which he has allowed to creep errors here and there, to appreciate how promptly the workers in similar fields will take pleasure in publicly correcting them for his instruction and guidance in the

future. Such a person would soon come to appreciate the fact, a fact that science in all ages has appreciated, that truth-seeking is a very safe occupation, and truth-telling exceedingly useful.

A few years ago Doctor White made some excellent remarks upon this side of the question, when he said: "May we not, then, hope that the greatest and best men in the Church—the men standing at centers of thought—will insist with power, more and more, that religion be no longer tied to so injurious a policy as that which this warfare reveals; that searchers for truth, whether in theology or natural science, work on as friends, sure that, no matter how much at variance they may at times seem to be the truths they reach shall finally be fused into each other? The dominant religious conceptions of the world will doubtless be greatly modified by science in the future, as they have been in the past; and the part of any wisely religious person, at any center of influence, is to see that, in his generation, this readjustment of religion to science be made as quietly and speedily as possible."

My brief connection with this university, as an invited lecturer, has been an exceedingly pleasurable one, and this has been rendered especially so from the fact that it has convinced me of the great breadth of its views in respect to its relation to modern progress and modern thought; and still more from the fact that it proposes to institute methods and operations that will effectually carry scientific teaching into her curriculum and the scheme of her instruction. When a great Catholic University does this she takes a distinct step in advance, and expresses the courage of her convictions that her faith surrounds the true kernel of religion; and although the truths advanced by science may cast strong suspicions upon many of the long-cherished traditional beliefs, or even utterly refute them, she fears not those truths for they can have but the one effect of stripping away all that is unworthy of her and permitting that kernel, to which I have just made reference, to shine forth with the greater brilliancy and power.

In closing it gives me pleasure to tender my most sincere thanks for the courteous and hearty reception extended me by the members of this University; and, what has been even more gratifying to me, the compliment, which I most keenly appreciate, of the undisturbed and continuous attention which the Faculty, students and audience have so kindly bestowed upon my remarks from

the beginning of the first lecture to the close of the final one which I have had the honor to bring before you this evening.

Takoma Park, D. C.